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OF HEALTH

Founded 1876

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PRACTICAL OBSERVATIONS

ON

VENTILATING AND WARMING,

&c.

LONDON:
PRINTED BY R. GILBERT,
ST. JOHN'S SQUARE.

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PRACTICAL OBSERVATIONS

ON

VENTILATING AND WARMING

PUBLIC EDIFICES, DWELLING-HOUSES,
HOT-HOUSES, CONSERVATORIES, &c.

CONTAINING

A VIEW OF THE DELETERIOUS EFFECTS OF VITIATED AIR;

AND A

DESCRIPTION OF ALL THE VARIETIES OF

Grates, Stoves, Furnaces, and Steam Apparatus;

WITH A

COMPARATIVE ESTIMATE OF THEIR MERITS FOR ECONOMIZING FUEL
AND PREVENTING SMOKE.

*ILLUSTRATED BY NUMEROUS ENGRAVINGS, FROM DESIGNS BY
R. S. MICKLEHAM, CIVIL ENGINEER.*

SECOND EDITION, WITH ADDITIONS.

LONDON:
PRINTED FOR THOMAS AND GEORGE UNDERWOOD,
FLEET-STREET.

1829.

PREFACE

TO THE

SECOND EDITION.

In consequence of a demand for a new Edition of the "Theory and Practice of Warming and Ventilating public edifices and other buildings," the author has thought it necessary to extend considerably his former observations on the important subject of Ventilation, in consequence of the almost universal introduction of coal-gas or oil-gas for artificial lights.

The subject is now become one of vast importance to the health and comfort of a very large portion of the middling and operative part of the community, who are com-

pelled to attend the business of their employers in premises which are lighted by gas: for it is the opinion of many experienced medical practitioners of the day, that asthma and other pulmonary complaints, have become decidedly more prevalent since the general introduction of gas-lights in the interior of houses.

The gradual and insidious progress of pulmonary disease renders it in most cases extremely difficult to trace the source from whence it originates. Complaints are, in the greater number of instances, ascribed either to original malformation of the chest, or predisposition of habit from hereditary causes; when, perhaps, the real source, if attentively investigated, would turn out to be merely an exposure of the individual for a considerable length of time to a very depraved atmosphere.

Our habits of life, as well as the employment of the two senses of taste and smelling, enable us to judge with tolerable ac-

curacy with regard to the quality of our food. But it is well known, that the atmosphere may be impregnated with highly deleterious gases, without our being able to discover them by the olfactory nerves; or without the power of preventing their deleterious agency on the animal functions, when taken into the lungs, during the process of respiration.

The depravation of the air by the combustion of gas, has never been sufficiently pointed out to public attention. The advantages of gas for lighting the public streets, cannot for a moment be denied. It is not only more economical, but it is peculiarly adapted for exterior lights from being less liable to be extinguished than oil lamps.

It is not to be expected that the coal-gas companies should point out the disadvantages attached to the use of gas in the interior of houses. Their immediate interests will induce them to leave this discovery to the sagacity of their customers. Indeed,

there are persons to be found who are hardy enough to assert that gas is even more salubrious than any other kind of artificial lights for the interior of buildings: but such an assertion can only be hazarded by persons interested in gas works, or totally unacquainted with the chemical changes produced in atmospheric air by the process of combustion.

The depravation of atmospheric air from the use of gas lights, is a subject demanding the most serious consideration. A great number of persons assembled together, as in the more frequented Churches and Chapels, and especially in crowded Theatres, will always vitiate the atmosphere to a certain extent, without the addition of artificial lights. But as the latter description of buildings are only frequented in the evening, when lights are indispensable; it is incumbent on the proprietors or managers of such concerns, to consult not only their own pecuniary interests, but the health and accommodation of that community for

whose amusement they profess to conduct their establishment.

The melancholy accident which happened at Covent Garden theatre a few months since, forcibly illustrates the danger to which all public places are liable where either coal or oil-gas is employed for illumination. Under what was previously considered good management in the manufacture and distribution of the oil-gas with which this theatre was lighted, a sufficient quantity, it seems, had imperceptibly escaped from the pipes or apparatus, to render the atmosphere of the theatre almost insupportable for many weeks previous to the fatal accident. Had proper vigilance been employed by the managers of the concern, the presence of this noxious vapour ought to have attracted earlier attention. There existed the most imminent hazard of an explosion taking place during the time of performance, by which many hundred lives might have been sacrificed, either by fire, by the falling of a portion of the building, or by the dreadful confusion which

must ensue from the audience rushing towards the doors on such an alarming event.

But independant of the risk of this fearful calamity occurring from a leakage of gas in the basement, so as to produce an explosive mixture with the surrounding atmosphere ; it is quite impossible for any individual labouring under any pulmonary ailment, or, indeed, any but those who are in possession of the most robust health, to breathe such an atmosphere without serious injury to the respiratory functions and the general health.

The vapour of oil-gas, though not quite so offensive to the olfactory nerves as coal-gas, is, perhaps, no less injurious to the animal functions. Coal-gas being a compound of hydrogen and carbon, with a sensible quantity of ammoniacal gas and sulphuretted hydrogen in combination, it is the latter gases which are so highly offensive when coal-gas is suffered to escape into the atmosphere without undergoing combustion. Oil-gas, however, from its greater

density, or in other words, having almost double the proportion of carbon in combination, must be considered as even more noxious to animal life than coal-gas. For it is the carbon which exists in narcotic poisons, and in the gaseous form of carbonic acid, which occasions death on being taken into the stomach, or inhaled by the lungs. Consequently, inasmuch as any carbonaceous matter already exists in the atmosphere, so far will it become poisonous in the function of respiration.

The density of oil-gas produces also another disadvantage in the event of escaping from any stop-cocks or pipes. From being nearly equal in specific gravity to atmospheric air, it will occupy the lower portions of the passages of a building where it escapes, and be more liable to blend with the atmosphere of such a place, and produce an explosion, than an equal volume of coal-gas. The dreadful calamity which occurred at Covent Garden theatre, arose chiefly from this source. The density of the gas

prevented its escape from the passages in the basement of the building; and on carrying a light in a recess where a quantity of the oil-gas and common air formed an explosive mixture, the lamentable explosion took place, which mangled several unfortunate beings; two of whom subsequently died in the hospital, while the unhappy men who fled for shelter into some of the adjacent passages, met a more immediate, though less painful death, by instant suffocation.

Another partial accident from the explosion of gas, took place last season in one of the lobbies of the King's theatre, during the time of performance. This accident produced a dreadful state of alarm among the audience, from the cry of fire, and the rush of persons to the doors. It was supposed to have originated from some malevolent person turning off one of the gas-burners, so as to allow it to escape unconsumed. Be that as it may, the facility of accomplishing such a diabolical act, ought not to be left in the power of any indivi-

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dual; more especially, in a place where many hundred lives might have fallen a sacrifice, if the explosion had been more violent.

The audience of every theatre where gas lights are employed, must be subjected to one of two serious evils:—they must either sit with the box or pit doors open, so as to admit a strong current of cold air through the house, and thus contract catarrhs and rheumatism, which may endure for life and bid defiance to professional skill; or, they must submit to the scarcely lesser evil, though less apparent at the moment, of remaining four or five hours inhaling an atmosphere which is infinitely more impure and poisonous than the *malaria* of the pontine marshes of Rome, or the swampy districts of Sierra Leone.

That all artificial lights, by rapidly consuming the oxygen of the air, or in other words, converting it into carbonic acid, tend to vitiate the air for respiration, must be

sufficiently obvious, even to the most common observer. But, owing to the delay which takes place during the process of combustion, in converting oil, wax, or tallow, into inflammable vapour, there is sufficient time allowed for the supply of atmospheric air to maintain combustion, without greatly impairing the salubrity of the air of the apartment for the purposes of respiration. The case is, however, widely different when the combustible body already exists in the gaseous state. Without a far more rapid supply of fresh air than is compatible with domestic or social life, the atmosphere of any apartment or public edifice will be greatly depraved by the employment of gas for artificial lights.

It is also very generally supposed that the recent destruction of the Glasgow theatre by fire, was occasioned by the gas with which the theatre was lighted, having formed an explosive mixture from a leakage in the pipes, or leaving open the stop-cocks. It is, however, impossible, in most cases, to

trace the origin of fire after it has taken place.

It is satisfactory to find that the managers both of the King's theatre and Covent Garden, have discontinued the use of gas in the interior of their respective edifices, though it is partially retained in the lobbies and saloons of the latter, and is yet highly offensive on first entering or quitting the theatre. Indeed, the public, or the Secretary of State on their behalf, ought to insist on the entire abolition of the use of gas from every theatre or place of public amusement in the metropolis, and the substitution of sperm, wax, or the best purified oil in its stead.

The saving of a few pounds per annum in the finances of such concerns, is not for a moment to be placed in competition with the constant probability of an explosion,—the additional risk of fire taking place where gas is used instead of oil,—and lastly, the constant depravation of the air from the combustion of gas.

In order that we may not be accused of advancing any invidious or unfounded charges against the management of the several gas establishments of the metropolis, we here take leave to remark, that every possible attention appears to be devoted by the several coal-gas companies, to the purification of their gas. But whatever pains may be taken to purify gas, it can never be effectually divested of its poisonous properties, so as to render it fit for the interior of a theatre, or any public building. A much more rapid supply of atmospheric air, as we before observed, is necessary for the combustion of gas, than is requisite for wax, sperm, or oil-lights; at the same time, the disengagement of carbonic acid gas by combustion, into the passages and body of the theatre, is so rapid as to bid defiance to ventilation, without the total sacrifice of comfort by the admission of currents of air.

But in every instance, where gas is employed for artificial lights, provision ought to be made for carrying off the carbonic acid

resulting from the combustion, more especially, in those cases where the parties are so negligent as to open the stop-cocks too wide, and allow more gas to escape than can obtain an adequate supply of air for perfect combustion. The bell-formed glasses or metal globes which are suspended over gas-burners, have a very trifling effect in condensing the vapour. A small portion of ammonia and sulphureous-acid gas is deposited on the interior of these receivers; but the carbonic acid being incapable of condensation, is wholly returned and allowed to mix with the air of the apartment.

The only effectual mode of carrying off the vitiated air from the combustion of gas, is that of having a conical tube fixed immediately over the burner, and leading out through the door or window into the open air. This mode of ventilation might be employed with advantage for every kind of artificial lights. It could be fitted in the form of a canopy or dome over wax candles, oil-lamps, or lustres, with a tube lead-

ing up from the centre. And if formed of glass or polished metal, which would allow of its being kept clean, it might be rendered rather ornamental than otherwise, to a ball room or assembly room of any description.

This mode of ventilating any crowded apartment or public edifice, would also be equally available in the day time, when artificial lights are not requisite. The vitiated or carbonic acid gas, evolved during respiration, in the first instance, rises towards the ceiling, till its temperature equals the general temperature of the room; and if it finds no outlet, it must, from its density, descend and mix with the air of the apartment, and be again carried into the lungs by respiration. But if only a single lamp be lighted immediately beneath a pipe with a dome or canopy, a current of deteriorated air will be driven through the pipe, and, of course, an equal volume of fresh air must supply its place.

When we take into consideration the fact, that from one-fourth to one-third of the

oxygen of the atmosphere of any apartment is converted into carbonic acid by the process of respiration; and that without a constant renewal of air, at the rate of four cubic feet per minute, for each person *, we are compelled to breathe a portion of air which has repeatedly been previously inhaled by other persons; it seems a matter of astonishment, that so little attention has been paid to the subject in a country which is distinguished for improvements in science and the arts.

In large edifices, such as chapels, or law-courts, or lecture-rooms, which are frequented by a great number of persons, several lamps might be so disposed as to connect with a main pipe, and greatly aid the purification or ventilation of the air. If the sight of lighted lamps be considered objectionable by day light, they might be covered with a shade like a dark lanthorn, and still perform the office of ventilators to the apartment.

* Vide Chap. XII.

It is a remarkable fact, that medical men in general should have hitherto paid so little attention to this subject. Even the construction of lecture-rooms or theatres for anatomical dissections, are not ventilated in a way that ought to be expected from scientific men. To shew that the charge of inattention to this important subject is not universal, we may instance the superior treatment of fevers at the present day, as compared with the former practice; and quote the judicious observations of a medical author, in a work lately published *.

" Of all the great advantages that have been procured to mankind by an improvement in medicine, these two stand in front, —that we employ food less copiously, and fresh air more freely. The benefit of free air in the interior of buildings, was placed in the strongest light, by what took place a few years back in the Dublin Lying-in-Hospital. Out of 7650 infants born in that es-

* " On Indigestion, and the Diseases of Children," by D. Uwins, M.D.

tablishment, 2944 died within the first fortnight after their birth, or nearly one third of the whole number. They almost all died of convulsions, many of them foamed at the mouth, the face was swelled, and looked blue as if they were choaked. This last circumstance led the physicians to conclude, that the rooms in the hospital were too close, and hence that the infants had not a sufficiency of good air to breathe; they, therefore, set about ventilating them better, which was done very completely. The consequence has been, that not one child dies now, where three used to die."

"Bad or confined air (says the same author) is a primary source of indigestion, and ought to be avoided with solicitude. Indeed, that pure uncontaminated air is especially proper for the dyspeptic, every thing loudly proclaims; and independent of the good or bad qualities of the air, the circumstance of *change* alone often operates wonders."

The absolute necessity of obtaining a

constant renewal of atmospheric air for respiration, and the dangerous consequences of allowing the introduction of gas in the interior of dwelling houses, or places of public resort, has been shewn both by Sir H. Davy's researches; and illustrated also by one of the most scientific physicians of the age, in the following terms*: "If exercise be useful during the period of sanguification, pure air is no less so; and I shall take this opportunity of entering my protest against the introduction of *gas* in the interior of our houses. *Carburetted* hydrogen is a deadly poison; and even in a state of great dilution, it is capable of exerting a very baneful effect upon the nervous system. I have been consulted on several occasions for pains in the head, nausea, and distressing languor, which evidently had been produced by the persons inhaling the unburnt gas in the boxes of our theatres. In order to afford additional support to the objections which I have urged on this occasion, I may quote an account of the ef-

* "Paris' Treatise on Diet," &c.

fects produced upon Sir Humphrey Davy by the inspiration of carburetted hydrogen gas.—'After a forced exhaustion of my lungs,' says Sir H. Davy, 'the nose being closed, I made three inspirations and expirations of the gas. The first inspiration produced a sort of numbness, and loss of feeling in the chest, and about the pectoral muscles. After the second inspiration, I lost all power of perceiving external things, and had no distinct sensation, except a terrible oppression on the chest. During the third inspiration, this feeling disappeared. I seemed sinking into annihilation, and had just power enough to drop the mouth-piece from my unclosed lips. A short interval must have elapsed, during which I respired common air, before the objects about me were distinguishable. On recollecting myself, I faintly articulated, *I do not think I shall die.*' After this proof of the poisonous nature of carburetted hydrogen gas," adds Dr. Paris, "after the cases of sickness and head-ache which have occurred, in consequence of its inhalation at the theatre,

am I not borne out in my opinion, *that its introduction into our apartments is fraught with danger?*"

The only remark the author would add to the high authorities above mentioned, as to the deleterious nature of gas in the interior of private houses, or crowded edifices, is that the severe inconvenience he has often experienced from breathing such an atmosphere for a few hours, is so great, as to prevent him entirely from frequenting any public place of recreation which is furnished with gas lights.

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CHAPTER XXI.

INTRODUCTORY OBSERVATIONS.

CONSIDERING the rapid advancement which practical science has undergone in Great Britain during the commencement of the nineteenth century, it is very remarkable that so important an object as that of economising fuel, should not have attracted more general attention. Whether a certain degree of negligence in this interesting branch of our civil and domestic economy may not have arisen from the circumstance of this country being more peculiarly favoured than any in Europe with an almost unlimited supply of fuel, it would be difficult to determine. To whatever source it may be referred, however, the fact is unquestionable, that there exists even at

the present day, in England, a greater disregard to the subject of warming dwelling-houses by the most effective and economical methods, than is to be found in any other state throughout Europe. Much of this inattention to the point of domestic economy doubtless arises from our national prejudices in favour of open stoves or grates. There is certainly something cheering in the aspect of a blazing fire-side. If it can be called a prejudice, it is a prejudice which it would be perhaps quite impossible to overcome; and to those with whom expenditure of income is of little consideration, the mere question of economy may perhaps be unworthy of notice.

But the term Economy must be, in the present case, taken in a much wider extent than that of applying to the actual saving of fuel effected by this or that construction of a stove, and its chimney or draught pipe. It is not merely the amount of heat given out to any apartment or suite of apartments by the combustion of a given quantity of fuel, but the

manner in which that object is accomplished; so as to deteriorate the air of such apartment as little as possible for the purpose of respiration, and also to avoid producing a current of cold air through the room for the supply of the burning fuel with an adequate portion of oxygen gas to maintain combustion.

It might appear somewhat ungracious to stigmatize the inventions and domestic arrangements of our forefathers with the term *barbarous;* but it would be difficult to point out any part of our usual domestic edifices which exhibits such a total absence of scientific principles, as the construction of our fire-grates and their appendages. It would seem, from the arrangement of the doors and fire-places, even in most of our better class of mansions, as if the architect had in view the interests of the coal merchant and the physician, at the expense of the pocket and the health of the owner or occupier. For it would be difficult to devise any more effectual means than many of our fancy stoves furnish, for the rapid combustion of fuel, and

the loss of heat in the apartment, by allowing a powerful current of cold air to sweep the lower part and drive the heated air immediately up the chimney shaft. At the same time a person or persons being placed round the fire-place of such a room, is absolutely in much greater danger of what we usually term "taking cold," than if exposed to the open atmosphere, with the thermometer standing at the freezing point.

It cannot admit of a doubt that a numerous class of our prevailing winter disorders, such as catarrh, rheumatism, &c. derive their origin from the anti-social construction of our ordinary apartments. And these results are more to be apprehended in proportion to the number of persons in a room of ordinary dimensions. For in such cases some persons must of necessity be placed in the immediate front of the fire-place, whilst others will be at the opposite extremity of the current of air; or in the immediate vicinity of the door or windows.

The consequences of this absurd attachment to old plans and defective principles, for the purpose of preserving what is termed "uniformity" in a building and its apartments, are too well known to every one who has been placed in such an aerial thoroughfare, to require illustration here: and it has become the fashion, in the construction of houses of the better class, to endeavour to remedy this evil by partially stopping out the supply of atmospheric air by lining the apertures of the doors and windows. It is obvious, however, that a deficient supply of air will not only diminish both the brilliancy of any artificial lights in such apartments, and the perfect combustion of fuel in the grate; but the atmosphere of such a room will also be, in consequence, greatly depraved for the purposes of respiration.

In addition to the personal inconveniences felt by the arrangements of our winter sitting rooms, the waste of fuel is enormous, from the very imperfect combustion of the coals

used in our open grates, and the great quantity of smoke evolved; which passing through the chimney shaft, its heat becomes lost to the apartment, while the warm air of the room follows the same route, and is again succeeded by a current of cold air from the windows or doors.

CHAPTER I.

THEORY OF COMBUSTION.

A CURSORY view of the process of combustion, will serve to shew, that the heat evolved from ignited fuel is principally dependant on the rapid supply of oxygen from the atmosphere; though considerably modified by the proportions of carbon and hydrogen in the combustible substance.

Every inflammable substance which we employ for giving artificial light, as wax, spermaceti, oil, tallow, &c. becomes reduced to a gaseous state, forming carburetted hydrogen gas, previous to uniting with the oxygenous portion of the atmosphere. During which process, both light and heat are evolved, and carbonic acid gas, with some

azote, and aqueous vapour, forms the residuum.

During the combustion of coke, charcoal, and a few varieties of coal, very little, if any flame, is produced; there being a very small portion of hydrogen gas present: consequently the gaseous residue of such substances contains little, if any, moisture, but consists principally of carbonic acid and azote.

It has been ascertained, from repeated experiments, that pure hydrogen gas requires half its own volume of oxygen gas to form the constituents of aqueous vapour. And when these gases are mixed in these proportions, and exposed to the temperature of about 700° Fahrenheit, they unite with explosive violence, leaving a particle of water not more than about 1 : 2000, their original volume.

Carburetted hydrogen gas requires more oxygen for its perfect combustion, than pure hydrogen; and that in proportion to its density, or the quantity of carbon in suspension. Thus coal gas, or sub-carburetted hydrogen, of

the spec. grav. 500, requires one and a half its own volume, or three times more oxygen than is necessary for pure hydrogen: and oil gas, or carburetted hydrogen, of a spec. grav. 960, (common air, 1000), requires three times its own bulk, or six times more oxygen for its perfect combustion, than pure hydrogen. Now, the comparative density of oxygen gas and good coal gas, is nearly as 2 : 1, (ox. 1100, coal gas 550); consequently we shall have to supply coal gas, during its combustion, with three times its own weight of oxygen, from the atmosphere.

From the process of gas-making we are likewise able to estimate the probable consumption of oxygen during the combustion of a given quantity of fuel.

The average quantity of gas obtained from a chaldron of good Newcastle coal, may be taken at the lowest estimate, at about 12,000 cubic feet. But a considerable portion of combustible matter is also evolved in the form of tar-vapour; which becomes condensed in

the vessels, leaving the gas to pass on to the purifiers and gas-holders. After these volatile products have passed over, the weight of coke remaining in the retort is equal to more than one half that of the original weight of the coal.

Now, if we allow 18,000 cubic feet of oxygen for the combustion of the 12,000 feet of purified gas obtained from each chaldron of coals; and one third of that quantity, or 6,000 extra (which is probably not too much) for the combustion of the bituminous portion usually deposited in the form of tar, in the gas-works, we should thus require a quantity of oxygen, from the air, at least double that of the whole gaseous product of the coal; or 24,000 feet for each chaldron of coal consumed.

But this probably will not amount to one half the actual quantity of oxygen consumed by our domestic fires; for it only refers to the *volatile* portion of the fuel. It is not so easy to determine the quantity of oxygen consumed

during the combustion of solid fuel, as coke, charcoal, &c.; for part of the oxygen becomes absorbed or fixed in the form of an oxide of carbon in the first instance, though ultimately given off in the form of carbonic acid gas.

The durability of the solid portion of coal, or that which remains after the compound gas has escaped, is probably more than double that of the hydrogen or flame. And as Sir H. Davy, Mr. Brande, Dr. Ure, and other eminent chemists have proved, that 100 cubic inches of carbonic acid consists of 33.8 grains of oxygen gas, and 12.7 grains of carbon in a gaseous form; it follows, that for every 12 lbs. weight of charcoal or coke consumed, (supposing them to be nearly pure carbon), we should require, avoiding decimal parts, about 33 lbs. weight of oxygen gas to effect their perfect combustion.

But previous to a mass of coal being brought to the state of coke, or what we call a "live cinder," it has given out from one third to one half its weight of carburetted hy-

drogen and bitumen, which, as have been already shewn, must have required a volume of oxygen gas equal to twice its own bulk and four times its own weight, for its perfect combustion.

It will, consequently, from the preceding *data*, be evident, that if we could take 20 lbs. weight of good Newcastle coals, and submit it to distillation and perfect combustion, without losing any of the product, we should require for that purpose a supply of oxygen gas from the atmosphere, or some other source, as follows: Supposing the coal to give out 8 lbs. of carburetted hydrogen, or other combustible gas, it would consume four times its own weight, or 32 lbs. of oxygen: and as before observed, the 12 lbs. of coke would require 33 lbs. of oxygen, to convert it into carbonic acid; or $32+33=65$ lbs. weight of oxygen requisite for the perfect combustion of every 20 lbs. of coal consumed.

Now, if we consider the atmospheric air as consisting of four volumes of nitrogen and

one volume of oxygen, and the relative densities of these constituents, as 0.972 to 1.112, (according to the best authorities), we should have, in 100 cubic inches of air, weighing 30.8 grains, about $972 \times 4 = 3888$ for the weight of the nitrogen gas, and 1.112 for the weight of oxygen in a volume of atmospheric air: or about 22 per cent. of oxygen in weight. If, however, we consider atmospheric air (agreeable to the most rational chemical theory of *definite proportions*) as a compound of $4 + 1$ atoms, or 80 and 20 parts of the respective gases in every 100, we should find, in practice, that for every pound of coal consumed, and which requires 3.25 pounds weight of oxygen, it would be necessary to furnish about $16\frac{1}{4}$ lbs. of atmospheric air, or in round numbers about 266 cubic feet.

This calculation presumes the whole of the coal to be capable of decomposition without residuum; whereas the very best kinds of coal leave a certain portion of earthy matter,

in the form of ashes. It is also presumed that the volatile matter of coal has been all converted into carbonic acid or other invisible gas, instead of a certain portion being deposited on the sides of the chimney flues; as is always the case in our ordinary fires. The latter point, however, so far from rendering our estimate incorrect, serves to prove the necessity of this vast supply of oxygen in order to produce perfect combustion; for it is in reality the want of this adequate supply of oxygen which allows the carbonic vapour to deposit itself on the chimney flues, producing not only a great nuisance, by accumulating in masses so as to obstruct the passage of the heated air through the chimney, and returning the smoke into the apartment; but it is also attended with a very considerable waste of fuel, and the loss of heat at the same time.

CHAPTER II.

COMPARATIVE VALUE OF DIFFERENT SPECIES OF FUEL.

THE preceding estimate of the process of combustion, however, requires some modification when applied to different species of fuel. Mineral coal, (as it is termed) forming perhaps nine-tenths of the whole fuel consumed in Great Britain, it becomes of more immediate importance that we should investigate with attention the usual modes of employing that kind of fuel, with a view of producing greater economy in its consumption. For although the supply of this invaluable natural product at first view would appear to be limited only by the demand for its consumption; yet, at the present rate of consumption, it is the opinion of one of the first coal viewers in the north, that the mass

of coal known to exist in the Durham and Northumberland coal-field, is not equal to more than 500 years' consumption. Consequently, if the population of this island continue its present ratio of increase, the demand for fuel will be in the same proportion; and the strata of this valuable mineral may become exhausted, in probably a couple of centuries, unless greater economy be adopted in its future consumption.

But if the interests of posterity be thought too remote to demand our attention, the question becomes one of immediate application when viewed under the head of civil and domestic economy. And one of the chief objects in the present essay, is, to demonstrate that an enormous waste of fuel constantly takes place, not only in our domestic fires, but in most of the stoves and furnaces employed in various kinds of manufacture, from a deficient supply of air and imperfect combustion of the fuel in the first instance; and secondly, from the loss of heat sustained by

the mal-construction of the stove and its appendages.

Previous to pointing out the several defects in principle, in the construction of our fire-places, or suggesting the means of obviating these defects; it will be convenient to take a short view of the distinction between coal and wood employed for the purposes of fuel. It has been satisfactorily proved by Dr. Thomson, Dr. Henry, and various other able chemists, that mineral coal of the better kinds, when decomposed, yields carburetted hydrogen gas, (mixed with a small portion of carbonic acid and sulphureous gas); bituminous matter in the form of tar, (mixed with ammonia); and a considerable residuum of coke; or the solid carbonaceous matter of the coal, united with a portion of alumine or other earthy substance.

The distillation of the ordinary kinds of fire-wood shews that its constituents vary considerably from that of coal.

The first product which comes over, is

the aqueous vapour of the wood in a state of mixture with the pyroligneous or acetic acid. Next follows a rapid evolution of gas, which is found to be hydrogen, slightly impregnated with carbon; and is usually not more than half the density of the carburetted hydrogen obtained from coal. Then follows a portion of carbonic oxide gas, or carbon with its minimum supply of oxygen. After which remains the charcoal, or solid carbon, or nucleus of the wood. The combustion of equal weights of coal or wood in our ordinary fires, will therefore be materially different in their results. A pound weight of good Walls End coal is capable of yielding (by perfect distillation) five cubic feet of gas, while an equal weight of dry ash or hazel wood, will not produce above three and a half cubic feet.

For the purpose of affording artificial light, coal gas is much superior to that obtained from any English wood: the latter gas not having its hydrogen so fully impregnated with carbon, as in coal gas; or more espe-

cially in olefiant or oil gas. The specific gravity of these combinations of hydrogen and carbon seems to afford the best test for estimating their respective illuminating power. In consequence of the levity of wood gas, the durability and of course value of wood, as fuel, is in some measure diminished. The charcoal obtained from its combustion forms perhaps, for general purposes, the most valuable portion of its mass; for it possesses advantages over coal-coke, both in retaining a red-heat with a smaller supply of atmospheric air; and in being exempt from that portion of sulphureous matter and ammonia which all kinds of coal possess in a greater or less degree.

From the constitution of coal, it has been already shewn, that during its combustion coal gas consumes about four times its own weight of oxygen; one half the oxygen forming water, and the other half carbonic acid. But wood gas containing more hydrogen gas and less carbon, in a given volume, we ob-

tain a greater portion of aqueous vapour, and disengagement of heat than during the combustion of coal gas; while coal gas gives out more heat during its combustion than oil gas. —The theory of this evolution of heat is extremely simple:—hydrogen and oxygen, when burnt in conjunction, become reduced into the liquid form, while the caloric which maintained these substances in the state of gas becomes instantly given out to the air adjacent; producing a degree of heat proportionate to the rapidity with which the union takes place. But the combustion of carbon in oxygen gas produces no condensation in volume. The carbonic acid still retaining the gaseous form; consequently much less heat is disengaged than when hydrogen and oxygen are condensed.

It is also to be considered that no sensible quantity of sulphur exists as a constituent, even in the most resinous or oily species of wood; whereas this deleterious substance prevails in some varieties of mineral coal to such

an extent as to render them quite unfit for domestic purposes. And the coke obtained from coal (especially such as is produced in the closed retorts of the gas works) contains a large portion of sulphur; which not only vitiates the atmosphere of an apartment in a serious degree, but it requires an additional supply of atmospheric air to effect its transformation into sulphureous acid vapour; and subsequently to expel this dense and highly noxious vapour up the chimney shaft.

CHAPTER III.

COMPARATIVE SALUBRITY OF DIFFERENT SPECIES OF FUEL.

As a comparison of the salubrity resulting from the use of different species of fuel, or rather that of the degree in which they respectively vitiate the air for respiration, the statement may be taken as a near approximation, thus:—coke, or coal which contains much sulphur and little bitumen (as the Kilkenny and Welch coal or culm) is most highly noxious to animal life; owing to the want of sufficient hydrogen to carry off the sulphur and carbon by means of the chimney flue. The sulphureous and carbonic acid gases from their considerable gravity, descending into the lower parts of a room will very seriously deprave the

atmosphere for the purposes of animal respiration.

Coal, of the ordinary kinds, follows next in vitiating the air of a room. Those varieties being most noxious which give out the greatest quantity of sulphur, and but little carburetted hydrogen. A blazing or "free burning coal," as it is usually called, being more salubrious, especially for private or close apartments, than the more durable varieties; on account of the hydrogen or gas flame producing a better current up the chimney, than would result from a mass of ignited fuel without flame.

Peat, or turf though forming but a small proportion of the fuel used in England, constitutes the major part of the fuel used in Ireland and part of Scotland. This class of fuel (which may be termed coal in its incipient stage of condensation) is found in different districts in such various stages of compression or solidity, as to render any general statement regarding its density very imperfect. Peat or

turf, cut from the mountain or upland bogs in Ireland possesses a degree of solidity nearly approaching to that of coal; and a specific gravity a little exceeding that of water. Other specimens of more recent formation, and especially that cut from those vast tracts of bog-land called "live bog," (which produce a deposite or stratum of turf annually, by the growth and subsequent decay of a spongeous mass of vegetable fibre) is of so porous and light a texture as to be scarcely worth the expense of cutting. The best kinds of turf yield a brilliant white flame; and in point of durability, it may be said to be intermediate between coal and wood, when used as fuel. There is however a peculiar acrid vapour from the very best specimens of turf (probably from the ammonia and sulphur), which renders this fuel highly disagreeable to many persons unaccustomed to its use. And wherever good coal can be obtained at a moderate price, the latter is not only a more durable and convenient fuel than turf, but it is probably less

noxious to animal life, than the vapour produced by the combustion of even the very best kind of turf.

Charcoal employed as fuel in open fire-places, is highly deleterious to respiration. For although it is free from the nuisance occasioned by *visible* smoke, and therefore convenient as a detached fire on some occasions, (such as the drying of rooms after undergoing repair), yet it should never be employed for domestic fires, unless a strong current of air can be allowed to sweep through the apartment, in order to drive off the carbonic acid gas evolved. The density of this gas being one half greater than that of atmospheric air (or as 1520 : 1000), it will disperse itself in the lower parts of the room, instead of passing up the chimney shaft; if charcoal be used in an ordinary sitting-room, where a current of air cannot be permitted. In certain processes in the arts, charcoal fires are almost indispensable; but they ought never to be employed without the means of rea-

dily carrying off the carbonic acid by ventilation.

Wood, when employed as fuel, is less injurious to the atmosphere of a room than either of the preceding substances. The best varieties of English wood for producing a brilliant and quick fire, are ash, hazel, hornbeam, &c.; but oak and beach are the most durable. The quantity of light carburetted hydrogen given out from wood during combustion, not only contributes to that cheerful flame or blaze peculiar to wood fires, but, as we before stated, its levity causes it to ascend the chimney flue with rapidity, at the same time producing a current of heated air, which draws after it the vitiated air of the apartment in conjunction with the carbonic acid formed by the combustion. It is almost superfluous to remark, that, after the gaseous product, or flame of the wood becomes exhausted, the current, or draft of the chimney, becomes proportionably diminished. And although the live embers of charcoal will retain a state

of ignition even until they become entirely reduced to ashes, yet it is injurious to health for a person to sit immediately over such embers; from the quantity of carbonic acid gas evolved by the charcoal.

It appears, therefore, that wood, employed for the purpose of domestic fuel, not only affords a more cheerful fire than charcoal, coal, coke, or peat; but that, when properly managed, it vitiates the air of an apartment in a much less degree, both from the product of the combustion consisting of less deleterious matter, and from its greater levity, producing a strong current of air through the chimney, and thereby effectually ventilating the room.

The combustion of any kind of light brush or faggot wood, in the grate of a room which is greatly confined, or which is suspected to contain a vitiated atmosphere, affords one of the most ready and most effectual means of ventilation; and should always be employed after an apartment has been shut up the pre-

ceding night with live coke or charcoal in the fire-place*. The effect of carbonic acid and sulphureous acid, though insiduous in its approaches, is so highly injurious to animal life, and more especially to invalids, that precautions of this kind in our dwelling houses, where the doors and windows are made almost air-tight, ought never to be forgotten by those who have the charge of such apartments.

* From some recent experiments of Dr. Murray on the anti-poisonous agency of acetic acid taken internally, we might infer that this acid, in the state of vapour, which is given out copiously during the combustion of green wood, would also have a salutary agency in correcting miasma in confined rooms.

CHAPTER IV.

HEATING PROPERTIES OF DIFFERENT SPECIES OF FUEL.

HAVING thus briefly examined the comparative value of the different kinds of fuel, as far as regards salubrity in use, and the production of artificial light; it will be proper to offer a few remarks on the most essential part of the subject, in our present view—the *heating* or calorific properties of the different species of fuel.

This part of our subject is less capable of definition, or demonstration, than the preceding, from the compound nature of the question regarding the *capacity* of different substances for caloric, or the matter of heat. It would be irrelevant to the present enquiry, to

enter into any disquisition concerning the *nature* of caloric. Whether it should be considered as a substance, *per se;* or only a quality or condition of all matter pervading nature, it will not in any degree affect our present enquiry. We shall therefore assume caloric to be that menstruum which holds oxygen in solution, in the state of oxygen gas;—and the capacity for, or rapidity of attraction, manifested for this matter by the different inflammable bodies, as the test of their respective degree of inflammability.

Now, the degree of attraction which hydrogen manifests for oxygen, appears to be greater than that of any other inflammable matter*. The union of oxygen and hydrogen, when ignited in certain proportions, forming the neutral liquid substance called water, warrants us in considering these two gases as the elementary matter of that liquid

* The intense degree of attraction which the new metallic bodies, potassium, sodium, &c. exhibit for oxygen, is not within the scope of our present enquiry.

in its opposite states of existence, and of aqueous matter held in solution by caloric.

It will perhaps serve to simplify and assist our enquiry, to consider all the compound inflammable gases, as hydrogen gas holding carbon, sulphur, phosphorus, &c. in suspension *.

Though carbon undoubtedly increases the

* The doctrine maintained by several eminent chemists with regard to the existence of *gaseous carbon,* appears altogether gratuitous. For we are not aware of the existence, in a single instance, of carbon in a gaseous form, *except in combination with other matter.* Though oxygen gas is capable of uniting with (or rather, holding in suspension) about 40 per cent. of its own weight of carbon; and hydrogen gas will dissolve about seven times its own weight of carbon (as we can prove by decomposing olefiant gas), yet we are no more warranted in saying that the carbon exists as a *gaseous* body, than we should be in calling a portion of sugar or salt, which is held in solution by water, *liquid sugar* or *liquid salt!* In the latter case we reproduce the whole of the solid matter in solution, merely by evaporating the water; while the whole of the carbon may be equally abstracted from carbonic acid gas, by washing it in any of the alkaline solutions.

intensity of the light given out during the combustion of these compound gases, yet it obviously retards the union of the hydrogen with the oxygen of the atmosphere. For the durability of carburetted hydrogen gas, when employed for artificial lights, is found to be in exact proportion to the quantity of carbon held in suspension; at the same time the inflammability of the gas, or its rapid union with oxygen is proportionably retarded. And as might be naturally expected, the heat given out during the combustion of these compound gases will follow the same law—its intensity must diminish in proportion as the hydrogen is impregnated with carbon.

That the most intense degree of heat we can produce artificially results from the violent attraction manifested by hydrogen for oxygen, is proved by that very beautiful invention, the oxy-hydro-blow-pipe of the late Dr. Clarke. In the operation of this instrument we may almost be said to have *no combustible body* present, though we have the

elements of *flame* in a high degree. For if the jet of compound gas (= 88 oxygen and 12 hydrogen) be thrown into a heated chamber of iron or porcelain, at any temperature above 700 degrees Fah. the gases instantly unite and form water; at the same time giving out an intense degree of heat to the adjacent media. Now this heat is nothing more than the sudden disengagement of that portion of caloric which previously existed in the two gases; holding, as it were, the elements of water in their ultimate or gaseous states of existence.

There is however an essential difference between the caloric existing in the form of steam or aqueous vapour, and that which exists in the form of oxygen and hydrogen gas. In steam, caloric exists merely in a state of mechanical or artificial mixture; from which it is disengaged by the contact of any media having at the moment a lower temperature. But in the form of gas, the caloric has lost its sensible properties and become passive or latent;

and is capable of maintaining its gaseous form under every reduction of temperature.

This view of the agency of caloric would lead us infinitely beyond our present limits were we to pursue the enquiry in detail, we must therefore confine ourselves to the immediate subject under consideration—the production of *artificial heat*—by tracing, briefly, the economical agency of oxygen during the process of combustion.

Although a more powerful degree of attraction seems to exist between hydrogen and oxygen than is manifested by the other inflammable bodies, yet carbon and oxygen unite also with great avidity ; and from the universal presence of carbon (forming as it were the nucleus of all kinds of vegetable fibre, and the chief constituent in all the varieties of animal and vegetable oils) it must be regarded as the basis of permanent combustion ; whilst hydrogen forms the basis of flame.

From the phenomena attending slow combustion, we should consider carbon as the *pa-*

tient and oxygen as the *agent*. For during the process, carbon is reduced to the gaseous state by the oxygen, forming carbonic acid: while the volume, and all other essential properties of the oxygen undergoes no change permanently.

Oxygen may therefore be considered merely as the vehicle for dissolving and carrying off the carbon given out by the process of combustion. Or, stated in another form—oxygen is the agent by which carbon becomes transferred from its solid state, or in combination with hydrogen; to that of an oxide, or neutral gaseous state, as in carbonic acid. But during this solution of carbon in oxygen gas, the more valuable part of the process as connected with civil economy takes place, the disengagement both of light and heat.

It is, however, worthy of remark that a very essential difference exists between the phenomena resulting from the union of hydrogen and oxygen, or that of carbon and oxygen: though both these processes evolve heat and

light. Hydrogen and oxygen as we before mentioned being condensed into the liquid form of water; the most valuable agent in nature. Whilst carbon and oxygen still maintains the gaseous form even when submitted to the lowest temperatures or to the most intense heat of our furnaces.

With regard to the valuable properties of fuel as applicable to domestic purposes, it would hence appear, that those substances which yield the greatest proportion of hydrogen will *cæteris paribus* be most valuable. Consequently the more inflammable varieties of wood ought to give out a greater degree of heat, in a given time, than an equal weight of coke or coal. From the evanescent nature of hydrogen and its compounds, it is however, necessary that if any kind of wood, or any of the vegetable or animal oils be employed for producing heat for domestic uses, that the combustion of these substances should be effected in *close vessels*; so that the heat be transferred immediately to the required point,

instead of being allowed to radiate or become lost by its escape into the atmosphere.

According to this view of the subject it will be evident, that a pound weight of wood would heat a given area or apartment 10 or 15 degrees Fah., in a much shorter period than an equal weight of coal, provided the heated air be not allowed to escape through the chimney shaft. For temporary purposes, therefore, as in apartments which require the temperature to be elevated a few degrees in a short time, it would appear that wood of good quality, or that which is most inflammable, possesses very decided advantages over coal or coke for heating apartments.

The most economical method of using wood for the purpose of fuel, is that of a close chamber stove, such as is in common use in Germany and the chief part of the north of Europe, and which will be described hereafter. If the plan of constructing our fire-places in this country for the burning of coal, be defective in principle, the mode of burning wood in our

farm houses and cottages is infinitely worse. From the fugacious properties of this fuel, it would not be too much to say that at least three-fourths of the heat produced from wood-fires (more especially the smaller kind or faggot wood) is lost to the apartment by its escape up the chimney. Whereas, the very small portion of carbon or soot that deposites itself from the smoke or vapour of wood, would allow pipes to be extended in a lateral or any other direction, so as to give out nearly the whole heat of the fuel to the building without producing any ultimate inconvenience by the choaking of the pipes. How long the present wasteful as well as inconvenient system of burning wood will yet prevail in the cottages of the poor of this country it is impossible to guess. For any person endeavouring to convince them of their want of economy in this respect, would have to contend both with ignorance and prejudice in favour of every old custom, however absurd.

Improvement must, in such cases, doubtless

emanate with the better classes. But it is to be feared that very valuable class of our population, called the "English Yeomen," are not much more exempt from prejudice against all kind of improvement, than their more humble neighbours. It is therefore almost hopeless to expect that any suggestions should prevail over those who employ wood for fuel in this country, to adopt the infinitely more economical plan of burning it in a close stove; notwithstanding the high price of fire wood in many inland parts of the kingdom, where coals are not to be procured, but at a still greater price. To such persons it is only necessary to observe that,—in spite of the self-complacency of our countrymen generally, in considering themselves so many degrees superior to foreigners of every nation, in civilization and the useful arts—the subject of the present essay is much better understood, and the due management of fuel for the purpose of producing the greatest effect from a given quantity is better practised throughout every

country in Europe than it is in Great Britain at the present day.—At a period too, when the useful arts in England are making the most gigantic strides in advancement; and more especially that class of the arts which is altogether dependent on, or chiefly connected with the consumption of fuel.

With regard to the question of economy in the consumption of coals in our steam engine furnaces, founderies, &c. the subject has met with a proper degree of attention from the number of ingenious men who have employed their talent in the various improvements made of late years in these valuable inventions; though in many of the minor operations of the arts, where fire is employed in the process, a great waste of fuel still exists, from the misconstruction of the apparatus or a mismanagement of the fire. But the quantity of fuel wasted in this manner bears no proportion to the enormous waste occasioned by the mal-construction of our domestic stoves or grates. And, what is perhaps of not less consequence to

the inhabitants of large or populous towns, the nuisance and unwholesome atmosphere produced by the evolution of such vast masses of coal-smoke.

CHAPTER V.

CONSUMPTION OF SMOKE.

This leads us to the question as connected with the destruction, or as it is termed the "consumption of smoke;" a point which has particularly engaged the attention of several scientific men within these few years past. It must be obvious, that the only possible way in which this desirable object can be accomplished, is, by causing the smoke which is given out from recent coal, to pass through a *red-heat;* either at the instant of its evolution, or before it ultimately passes into the chimney shaft.

Various plans have been devised for conveying away the smoke from such stoves as are

employed for heating spacious apartments or churches, where fire places of the ordinary construction attached to a chimney in the side walls would be inadmissible.

It must be acknowledged, that, so far as carrying off the smoke is concerned, these "air stoves," as they are called, are decided improvements in point of elegance over those which have a series of flue pipes leading from the top of the stove through the roof, or the outer walls of the building.

In point of economy, however, the air stoves are much inferior to those of the old construction. For the rarified air in conjunction with the smoke being made to pass downwards through the hollow back or sides of these stoves into the floor or chamber beneath, from whence it is carried out into the atmosphere, the greater part of the heat evolved from the fuel is carried out of the apartment the moment it is disengaged. Whereas, the heated air and smoke while passing through the range of flue-pipes, in stoves on the old

construction, will have given out the greater portion of its caloric previous to its arrival in the open air.

The same inconveniences will attach to both these plans of conveying off the smoke from detached stoves, in the liability of the flues or passages (whatever may be their area or figure) to become choaked up by the deposite of soot or bitumen of the coal. For notwithstanding the inventors of some of these fancy stoves *pretend* to consume the smoke, yet it is a mere pretence, for the purpose of recommending their inventions to public notice and patronage. It may be asserted, without the hazard of denial, that no modification whatever, of our domestic stoves, *on their present principles*, will allow of the consumption of their own smoke. From the very principle on which the draft or current of air in chimneys depends (and which will be hereafter fully described) the smoke or undecomposed carbonic matter cannot be entirely consumed; some portion will always make

its escape, in conjunction with the heated or rarified air produced by the combustion.

The deposite of soot in a chimney flue depends in a great measure on the mal-construction of these flues, not only from their too great capacity, usually, but from their lateral, or at least angular projections, obstructing the ascent of the smoke, and thus making it deposit its undecompounded carbon, or soot, against the sides and angles of the flue.

But the evolution of smoke depends in a great measure on the method of supplying the fire with fresh fuel; and still more, on the manner of giving the proper or sufficient supply of atmospheric air, in order to carry on the combustion.

Supplying a fire with fresh coals from above, must necessarily produce a considerable waste of fuel, from the immediate disengagement of a dense smoke, which carries off a great portion of the inflammable matter of the coal, in conjunction with the aqueous vapour and ammoniacal gas. And

this effect is increased in proportion to the quantity of recent coal thrown on at one time.

A very mistaken notion vulgarly exists on this point,—and which could scarcely have been suggested but by some one interested in the consumption of coal,—that it is economical to supply a fire with a large mass of fuel at once, rather than to add it occasionally, as may be requisite for domestic purposes.

If domestics could be made acquainted with the loss of heat sustained by adding large masses of coal at one time, and the consequent delay and inconvenience to their cooking operations, they would not so uniformly resort to this wasteful practice, on their own account, whatever disregard they may evince for the household economy of their masters. It is, however, pretty well understood, that the upper class of servants, in many families, *have a direct interest in the amount of the coal merchants' bill!* consequently, economical arrangements, for the more effectual combustion of fuel, as well as ordinary dis-

cretion in supplying domestic fires, become secondary considerations; or rather, are considered according to the *inverse ratio.*

It is also a source of constant complaint with those, whose ingenuity have devised any improvements in kitchen stoves and culinary apparatus, for the greater economising heat and preventing waste of fuel; that domestics, —more especially those important personages termed cooks—almost uniformly resist the adoption of these improvements, (either through ignorance, or from some less excuseable grounds), unless their employers have the firmness to retain the command of their own household, by making the adoption of any requisite improvement a *sine quâ non* in the services of such domestic.

Yet, it must be acknowledged that, in spite of all authority or mandate, our domestic comforts are so much under the controul of the aforesaid important class of persons, that the man must have some little temerity who defies, or dares to be on bad terms with the

head (whether male or female) of the culinary establishment!

The addition of small quantities of coal at one time, is far more economical than large masses, from the almost immediate elevation of its temperature, by which the inflammable gases ignite and form flame, instead of being driven up the chimney shaft, (or, as it often happens in chimneys badly constructed) being thrown out into the room in the form of dense smoke; such smoke being not only in itself an intolerable nuisance, but also carrying off that carbonic matter, and depositing great portion of it in the chimney, which ought to have been decomposed by the fire into carbonic acid gas, giving out light and heat to the surrounding apartment.

As the compound gases disengaged from coal in its recent state, are much lighter than atmospheric air, the smoke disengaged from heated coal must always ascend; which ascent is greatly promoted by the rarified air adjacent to the burning fuel following

the same route. It is therefore obvious, that the only way in which we can deflect this vertical column of smoke and warm air downwards, or in an opposite direction to that produced by its own specific gravity, will be to oppose a stronger current of cold air from above, so as to make the smoke pass through the ignited fuel, and thus be converted into carbonic acid or invisible gas.

This is the only principle on which the combustion of the floating carbon, or, as it is commonly termed, the "consumption" of smoke depends. There is not, in fact, any consumption of volume, in the gaseous matter, in this instance; but that portion of carbon which previously existed in the opaque form of smoke (or sub-oxide of carbon with perhaps a little hydrogen combined), becomes converted into carbonic acid, (or saturated solution of carbon in oxygen gas) by passing through the ignited fuel, and escapes in its invisible form, by the vertical or other flues at the back of the fire-chamber.

Now this principle has been adopted under different modifications, as to form and arrangement, by several persons, in order to destroy great part of the nuisance arising from the evolution of large volumes of smoke: And it has to a certain extent succeeded, where the construction of the fire-place is not immediately dependant on the nature of the manufacture or process carried on. It will, however, be obvious, that this mode of consuming smoke, can only apply to enclosed stoves, or fire-chambers. For the return of the column of smoke in an open-fronted stove or grate, would inevitably throw out the greater portion of its volume into the surrounding air of the apartment.

It is, moreover, essential, that the supply of air for combustion should be given from *above*, instead of *beneath* the fire, as in our present domestic stoves. As the different kinds of stoves which have been invented for destroying the smoke, and economising fuel, in the heating of buildings, will be described

under the proper head in the body of the work, it is only necessary here to add, that it appears to be quite impossible to apply the principles of economy in the management of fuel, to the greatest advantage, whilst our national taste makes us obstinately adhere to what is termed "the fashion;"—or, in other words, an attachment to mere conventional points of ornament or caprice; instead of utility, domestic economy, and health.

CHAPTER VI.

CHANGES INDUCED IN THE AIR BY COMBUSTION AND RESPIRATION.

It will be necessary to examine, with some degree of attention, the changes induced on atmospheric air by respiration, combustion, and fermentation;—by way of ascertaining the most ready and effectual means of counteracting the deleterious influence of such vitiated aerial matter, at the instant of its evolution: or, if that be impracticable—of suggesting the most economical way of dispersing such noxious matter, by a free supply of air from the atmosphere.

It has been satisfactorily shewn, by numerous experiments, conducted by the most eminent chemists and physiologists of the present age, that the change induced in atmospheric air by animal respiration, is nearly as follows:—A given portion of common air, (consisting of oxygen gas 21, and azote, 79; or, in round numbers, 1 of the former, and 4 of the latter), being inhaled into the air-cells of the lungs, and, after a few seconds, being ejected into a pneumatic jar or receiver, and subsequently examined by chemical tests, is found to have lost very little, if any, of its volume; but the oxygenous portion is become charged with carbon, under the form of carbonic acid gas. At the same time a certain quantity of steam, or aqueous vapour, is emitted; but whether this vapour is the result of any union between a part of the oxygen of the air and the hydrogen in the human frame; or whether it is due to the quantity of water or vapour, which the high temperature of the expired air would naturally hold in suspension

—has not yet been very satisfactorily determined. The latter presumption is far the more probable. For if any material portion of oxygen were absorbed, and condensed in the formation of water, (and we have already shewn, that every cubic inch of hydrogen would require half a cubic inch oxygen), the volume of the air expired from the lungs, would be considerably diminished :—whereas, the diminution in bulk is very slight, or scarcely appreciable, if the experiment be carefully performed, and the average of several experiments obtained.

The subsequent passage of this expired air through a portion of lime water, also shews that nearly the whole of the matter abstracted from the lungs, was carbon, or carbonic matter, accompanied by slight traces of ammonia and sulphur.

It has hitherto been considered by chemists of the first eminence, both English and foreign, that the salubrity or vitality of atmospheric air, depends almost entirely, if not

altogether, on the due proportion of the oxygenous part, and the exercise of its powerful agency in absorbing and carrying off the carbon, &c. of the blood, during the process of respiration. That ornament of British science, Sir H. Davy, during many of his elaborate experiments on the decomposition of the alkalies, proved that the azotic portion, or nitrogen of the atmosphere, resisted all attempts that could be made for its further decomposition, either by means of the galvanic battery, or by the combustion of the alkaline metals, potassium or sodium. Nitrogen is therefore entitled to the name of *simple* gaseous matter, perhaps in a greater degree than any other substance.

By farther experiments, the same illustrious chemist proved azotic gas to be the peculiar matter, or *base* of the nitrous or nitric acid; hence the term *nitrogen*, which is now more general, and perhaps more appropriate than the French denomination, *azote*. But, notwithstanding the peculiar properties of this

gaseous matter, and the circumstance of its constituting four-fifths of the entire bulk of the atmosphere, its agency in the economy of nature, appears to have been a point which philosophers have hitherto overlooked, or at least have assigned its operation to a very limited sphere, in the supposed production of natural phenomena.

Dr. Ure, in his invaluable Chemical Dictionary, thus concludes his notice of the present state of chemical research, with regard to nitrogen :—" Its uses in the economy of the globe are little undersood. This is likewise favourable to the idea, that the real chemical nature is as yet unknown, and leads to the hope of its being decomposable. It would appear that atmospheric azote and oxygen spontaneously combine in other proportions, under certain circumstances, in natural operations. Thus we find, that mild calcareous, or alkaline matter, favours the formation of nitric acid, in certain regions of the earth; and that they are essential to its production

in our artificial arrangements, for forming nitre from decomposing animal and vegetable substances."

Now the acknowledgment of so high an authority as Dr. Ure in chemical science, "that the uses of nitrogen in the economy of the globe are little understood,"—though calculated to make us despair of absolute success, in any such investigation; yet the writer of these Observations, feeling how intimately such enquiry is connected with the immediate object of the present work—has, with some diffidence, ventured to throw out the following remarks, *on the probable influence which nitrogen may be supposed to exercise*, not only in the functions of animal life, but also in other departments of the grand and beautiful laboratory of nature.

That azote, or nitrogen gas, does not *appear* to exercise any considerable agency, either in the respiration of animals, the combustion of fuel, or during the decomposition of animal and vegetable substances, is no proof that such

agency may not exist! That the powers of our organs of perception are limited, very limited—it would be presumption to deny. We may doubtless demonstrate and classify that portion of the operations of nature which is tangible to our imperfect powers; but with regard to that which is beyond our vision or perception—no small portion of creation!—we must content ourselves by merely reasoning from analogy, or employing synthetical calculation, in order to form any tolerable conception of the agency of a variety of matter in the grand arcana of nature. And, from the substance called nitrogen, having eluded the experimental researches of the most eminent chemists of the present age, we are the more justified in applying this mode of enquiry, to estimate the real nature of that interesting substance.

To suppose that the great mass of our atmosphere should be unemployed, or inert, in the great magazine of nature, while the minor part is known to be so important

an agent in the animal functions; would be, to suppose an inconsistency in the grand designs and objects of the Great Author of the universe, who surely cannot be imagined to have created a single atom in vain!

If nitrogen were either neutral gaseous matter, or a mere diluent of the oxygen of the air, it would, in all probability, not have constituted four-fifths of the entire mass, whilst one-fifth only is *apparently* employed in respiration, &c.

We know not whether the nitrogen of the atmosphere may not be equally instrumental in carrying off the hydrogen, (under the form of ammoniacal gas), as the oxygen is in carrying off the carbon as carbonic acid gas. We know certainly that the process of digestion and subsequent putrefaction, gives out a very considerable portion of compound gas; more especially from many varieties of vegetable food. And we are able to ascertain with tolerable accuracy, the nature of these gases,

which prove them to consist of hydrogen impregnated with carbon, sulphur, phosphorus, &c.

Now, without admitting the agency of nitrogen in this case, it would be difficult to account for the expulsion of this gaseous matter from the human body. Though it must appear to be equally necessary for the preservation of health, that this gaseous, or, as it may be called, alkaline and animal matter, should be carried off from the body; as that the carbon of the blood should be expelled from the system by the oxygen absorbing it from the air-cells of the lungs.

Or we should perhaps have stronger reasons to believe in the agency of nitrogen, as an indispensible in preserving the healthy functions of animals, if we take into account the vast quantity of transpirable matter given off from the surface of the body in a healthy state. Now although carbon may form a certain portion of this gaseous matter of the skin, yet our olfactory nerves demonstrate to us beyond a

doubt, that a considerable portion consists of the volatile alkali called ammonia, which alkaline gas is known to be a compound of hydrogen and nitrogen.

CHAPTER VII.

PROBABLE AGENCY OF HYDROGEN GAS IN NATURAL PHENOMENA.

Mons. Guy Lussac, in some late researches on this interesting compound, having demonstrated that 3 cubic inches of hydrogen gas, and 1 cubic inch of nitrogen, on being mixed together, become condensed into half their volume, or 2 cubic inches of ammoniacal gas, possessing a spec. grav. of 590, atmospheric air equal 1,000; or conversely,—100 cubic inches of ammoniacal gas, may be decomposed into 50 inches of nitrogen, and 150 of free hydrogen.

As hydrogen is known to be evolved in vast quantity by the decomposition of vegetable and animal substances; and probably during

the decomposition or evaporation of water also; we should be at a loss to account for the immediate disposal of such immense volumes of this gaseous matter, without allowing the agency of nitrogen gas for its reception, and condensation. From the extreme levity of hydrogen (pure hydrogen not weighing more than about 1:15 common air; or as .070 to 1000) it would ascend through the lower strata of the atmosphere with vast rapidity at the instant of its evolution, by the decomposition of vegetable and inflammable substances, provided it met with no obstacle to retard its progress.

The admixture of hydrogen and oxygen at the ordinary temperature of the air produces no perceptible *chemical change*, or reduction of volume; though their union at about 700 degrees Fah. is attended with such violent effects, from the disengagement of light and heat, and the consequent reduction of volume from 2.000 to 1. The admixture of hydrogen and nitrogen, on the contrary, enter into che-

mical combination at the common temperatures; attended with condensation of volume $=.5$ of the component gases. Hydrogen gas, therefore, on being evolved by the decomposition of vegetable matter, will be immediately arrested, and partially condensed, by coming in contact with the nitrogen of the air; while the oxygen of the air will not unite with hydrogen, until the latter forms more than three times its own bulk of the nitrogen present. Or, in other words, until all the nitrogen has been converted into ammoniacal gas. Which process would require (according to the proportions assigned by M. Lussac) 12 volumes of hydrogen to every 4 volumes of nitrogen in the atmosphere. Or, a quantity of hydrogen $=12{:}5$; or more than double that of the whole volume of the atmospheric mass!

Now however preposterous such a supposition appears at first view, something of this nature would obviously be the result, if the vast portion of hydrogen (and its com-

pounds carburetted, sulphuretted, and phosphuretted hydrogen) known to be constantly given out into the atmosphere by vegetable and animal decomposition, had no other agent to effect its removal than the oxygenous portion of the air. Which has been hitherto considered, or rather assumed to be the only "vital" portion of the atmosphere. Though we have endeavoured to shew that oxygen is not capable of uniting *chemically* with these noxious gases at the ordinary temperature of the air.

But in admitting the agency of nitrogen, as before mentioned: we have, in the first instance, a vehicle always present to seize upon and carry off the hydrogen gas from its usual combinations with sulphur, carbon, &c. as it becomes gradually evolved during the processes of organic decomposition. While these noxious substances will be again precipitated in the solid form, either immediately they become liberated from the hydrogen; or else by uniting in a state of mechanical mixture or sus-

pension with the oxygen of the air in the first place, and subsequently, be abstracted from this combination by the attraction manifested by lime and the other alkaline bodies.

This theory of the different states of existence in which carbon, sulphur, or phosphorus enters into combination with hydrogen, or with oxygen, is beautifully illustrated by the process of gas-making.

For the purpose of purifying Coal gas,—the crude gas after being passed through condensing pipes to arrest the undecomposed tar and ammonia, is passed through a solution of lime, or lime in a state of powder; by which means the whole of the sulphurous acid existing in the gas, as well as the chief part of the carbonic acid is arrested by the lime, forming sulphate and carbonate of lime. Whilst the carburetted hydrogen or pure inflammable gas passes on through the mass of lime without any material diminution of its volume.

We may, therefore, be allowed to call the former compounds in this case, by the

name of *mechanical* mixture, or suspension; while carburetted hydrogen is a *chemical* solution of carbon in hydrogen gas, and consequently not decomposable by other matter at the ordinary temperature of the atmosphere.

The routine which a portion of vegetable substance (or more properly carbon in conjunction with hydrogen, as the chief constituents of wood) undergoes in its different stages of decomposition may therefore be very nearly traced as follows:—By the fermentative or putrefactive process, part of the carbon of organised matter becomes carried off by the oxygen of the atmosphere, while the hydrogen, being disengaged, will fly off in a gaseous form. But we have seen that it will immediately enter into a new combination, by uniting with the nitrogen of the atmosphere, and forming gaseous ammonia. This ammonia will again be absorbed with great rapidity by any water which may be adjacent, while the carbonic acid formed by the oxygen of the air (including the carbonic or sulphu-

rous matter left behind by the hydrogen in forming ammonia) will be absorbed by any calcareous or alkaline substances adjacent. Chalk or limestone consisting of .44 of carbonic acid and .66 of lime.

CHAPTER VIII.

MEANS OF DETECTING NOXIOUS GAS IN HOUSES; AND OF COUNTERACTING ITS EFFECTS.

The purity or impurity of the air we breathe admits of a wide and most interesting field for investigation, not only as it influences the functions of animals, producing health or disease, but also as it affects vegetable life. But we cannot extend our limits beyond that of its immediate connection with the subject of the following pages.

By examining with attention what takes place during the deterioration of air by respiration, or combustion, we are enabled to employ certain means for obviating, or at least neutralizing, the noxious agency of such vitiated air upon animal life in general.

For example:—In any confined apartment

which does not admit of a current of air, a number of persons will very soon render such an atmosphere highly insalubrious; not only from the carbon thrown out from the blood, but also by the ammonia resulting from the transpirable matter of the skin.

Now we have previously stated, that water will absorb nearly 460 times its own bulk of ammoniacal gas; whilst a solution of lime will absorb from two to three times its own bulk of carbonic acid. It cannot therefore admit of a doubt, that, if we place an open vessel containing fresh, or pure water—or which would be preferable, water with a small portion of recent lime dissolved in it—in any apartment where the air has been much vitiated;—that the greater portion, if not the whole of the noxious matter will be absorbed. It would in such cases be advisable to stir or agitate the liquid, so as to bring its whole mass in contact with the air in succession: and also desirable to have it renewed, when the liquid may be supposed to be saturated with the gaseous matter. In the event of a

close room having its atmosphere depraved by the combustion of artificial lights; or which is still worse, by the combustion of charcoal or coke; a large vessel containing recent lime-water would have a most salutary effect, by absorbing the carbonic acid.

It is on this principle only that white-washing the walls of buildings is found so conducive to their salubrity. Recent lime absorbing carbonic acid from the air with considerable avidity. For this purpose, however, pure lime-wash is preferable to whitening; for the latter substance is already a sub-carbonate of lime, consequently it cannot evince so much attraction for carbonic acid, as lime in its recent state from the kiln.

In descending coal-mines, wells, cellars, or other subterraneous chambers, more or less carbonic acid gas is almost always found in a state of mixture with the air. In such cases, perhaps the only effectual way of purifying the atmosphere would be by expelling the noxious gas *mechanically*. That is, by

employing an exhausting pump with a leather hose, or pipe, reaching to the bottom of the chamber; (this gas being much denser than common air) or, which would be far better—using a condensing, or force-pump, to throw in atmospheric air; which would of course expel an equal volume of the noxious gas.

In those cases where such means are not applicable—If a vessel or vessels such as open mouth buckets containing lime water, were lowered into those chambers or cavities previous to any person venturing to descend in such hazardous situations, it would be the means of at least diminishing the danger, by absorbing some portion of the carbonic acid gas.

In order to ascertain whether carbonic acid gas exists in any vault, or other situation, (where, on account of its density it will always occupy the lowest level) a lighted candle or lamp may be employed with the greatest advantage. A candle attached to a long pole, or an open lanthorn suspended by

a rope may be lowered into the area or flooring of the vault. If the light burns dim, and becomes speedily extinguished, there is considerable danger in any man venturing down the vault or well. But if the light be immediately extinguished, it would be inevitably fatal to a man attempting to descend.

If, on the other hand, a light on being lowered to the flooring of such apartment, burns with its usual brilliancy, it is a proof that little, if any, carbonic acid gas exists in the atmosphere of such vault or cellar.

A great source of the carbonic acid gas in cellars, brewhouses, &c.; arises from that gas being evolved in great abundance by the fermentation of wine, beer, &c. But its accumulation, is in a great degree owing to the exclusion of atmospheric air, in order to prevent those changes of temperature so frequent in our climate; and which is so injurious to that equable fermentation found to be essential for all vinous liquids, destined to keep any considerable time previous to use.

In all wine and beer cellars, therefore, which are but seldom visited; or, in other words, are not often allowed to have any ventilation of the air; a vessel containing a solution of lime-water, with a wide surface, and placed in the lowest part of the cellar, would serve to absorb part of the carbonic acid gas; whilst it would not in any degree interfere with that equable temperature, which (for the reasons before mentioned) it is desirable to maintain in such situations.

The noxious and highly offensive effluvium which is evolved from certain other appendages to dwelling houses, might also be prevented in a great measure by the presence of lime-water; the gas emanating from such situations being chiefly sulphuretted hydrogen, which is rapidly absorbed by the alkalies. It is on this principle that vegetable and animal substances undergoing putrefaction do not give out any offensive odour when covered with any earthy matter:—as in forming a compost for the purpose of manure.

CHAPTER IX.

EFFECTS OF STAGNANT OR PUTRESCENT WATER IN VITIATING THE AIR.

The ordinary phenomena resulting from stagnant or putrescent water, though not obviously connected with the interior of buildings; is, nevertheless, so intimately connected with our immediate subject as to demand a few remarks in this place.

It does not occur to the writer of these observations that any actual analysis of the water obtained from stagnant ponds or ditches, has hitherto formed the subject of experiment with any of our eminent chemical enquirers,—though a point well worthy of investigation.

From knowing the constituent matter which

enters into the formation or production of stagnant water; we may infer, with tolerable accuracy, the nature of its contents: and calculate the probable effects of its subsequent evaporation or solution in the circumambient atmosphere.

In tracing the progress of gaseous matter through its different states of existence, we have already shewn, that water absorbs a vast quantity of ammoniacal gas. Now this gaseous matter may be always distinguished by its peculiar odour, the volatile alkali. And as might be inferred, the stagnant water of ponds (more especially where vegetable matter abounds) always exhibits the disagreeable effluvium of ammonia; particularly when agitated so as to disengage this gaseous matter.

But in many cases the smell of sulphuretted hydrogen, or that offensive gas which emanates from *cloacæ*, or other collections of animal matter, is also very distinguishable when stirring the water of ditches. The water also contains a small portion of light carburetted

hydrogen gas; as may be proved by filling a tumbler or wide-mouth bottle with water, and holding it inverted on the surface of such pond or ditch, while the water is stirred with a stick. When bubbles of this gas in combination with sulphuretted hydrogen, will rise through the water and displace the water in the bottle.—On being mixed with from 5 to 10 times its volume of atmospheric air, an explosive mixture will be formed, which may be fired by applying a lighted taper; care being taken to perform the experiment with a small quantity of the inflammable gas, and a wide mouth bottle, in order to prevent accident from the sudden expansion of the explosive mixture bursting the bottle.

Stagnant water may therefore be considered as a weak solution of ammonia; containing also a certain portion of sulphuretted or carburetted hydrogen gas; and the quantity of ammonia will obviously depend on the length of time and the quantity of vegetable matter in the state of decomposition; as well

as from the progress of evaporation of the aqueous particles; by which the alkaline matter will, of course, become more concentrated in proportion. Such putrid water, for instance, as the ditches or *dykes* of the lower levels, or fen-countries exhibit at the latter end of the summer, from the preceding evaporation, and the want of rain.

Now it will be easy, from these *data*, to explain the origin, (or at least the probable cause) of those intermittent fevers which are known to be peculiar to the districts before mentioned; and which are always most prevalent in the autumnal season, when the ditches, or stagnant water, become nearly evaporated.

While these ditches remain filled, or nearly filled, with water, the exhalations are probably confined almost entirely to the aqueous particles; but as the water evaporates, the alkaline, or deleterious matter, will at length follow the same course; and consequently impregnate the air of the immediate neigh-

bourhood with its noxious qualities. The bad effects of which will be greatly increased, if any kind of animal matter also exists, in conjunction with the putrid vegetable substances, or their residuum—ammonia, and the other deleterious gases*.

That this is the true theory of the production of putrid water, when exposed to the air,

* It is highly probable that the *mal-aria,* which renders the Campania in the vicinity of Rome so insalubrious in the autumnal months, is occasioned by the evolution of this gas. The flat surface of the land, and the want of drainage owing to the culpable idleness of the inhabitants, allowing the water to stagnate in the ditches; and with the heat of the climate very soon becoming putrescent: while the great rapidity of evaporation will at length render these ditches perfectly dry, and of course dissolve the alkaline or putrescent matter in the adjacent atmosphere.—In districts where water dikes or canals form the sub-divisions of the land, these receptacles of water should always be of sufficient depth to prevent their entire evaporation during the autumnal season. And, wherever it is practicable, they should also be supplied with a small stream of fresh water, in order to prevent stagnation and putrefaction.

is proved by the well-known fact, that rain-water, or river-water, which contains little, if any, *saline* matter in combination, is most liable to putrefaction; while spring-water, which contains usually some portion of saline or mineral substance, will keep sound for a longer period. And sea-water, or strong solutions of other minerals—as is well known—still farther resists the process of putrefaction; probably from the muriatic or other acids resisting the absorption of ammonia from the air.

The water of peat-bog has also the property of resisting putrefaction in a remarkable degree. But whether this is to be ascribed to the existence of the carburet of iron usually found in such bog-soil, or to other mineral matter in combination, is not exactly known. The fact is, however, of vast importance, as regards the salubrity of districts such as Holland, and the greater portion of Ireland, and parts of Scotland, and the North of England. For the stagnant ponds of water, (from

the rain filling the cavities from whence peat has been cut), and the swampy surface of bog-land in general, would render such districts perfectly uninhabitable, if the water of these ponds were equally liable to putrefaction with that of other stagnant ditches or basins.

The immediate consequences of the stagnation of fresh water, especially under the influence of a warm climate, appears to be the production of myriads of animalculæ; which minute animals, by their increase, serve greatly to accelerate the process.—Putrefaction of water may thus be almost said to be a process, *sui generis*; though it may be in a certain degree induced, by the absorption of that gaseous matter, (ammonia), which is known to form a large constituent in all animal, and many vegetable substances.

CHAPTER X.

EFFECTS OF VITIATED AIR ON ANIMAL LIFE.

ALTHOUGH it would not be consistent with the narrow limits of our present work, to enter into any enquiry as to the *mode* in which the mal-aria of marshy districts acts on the human frame; whether the deleterious matter known to exist in marsh miasma, be *absorbed* by the lungs, or the skin; or whether the atmospheric air loses part of its agency (as a vehicle for carrying off the feculent exhalations of the body) through being impregnated with the peculiar matter evolved from stagnated waters,—are questions more immediately connected with physiological research than civil or domestic economy.—Yet the

great—the intense interests, which are obviously involved in the better understanding of the probable source of those noxious matters that float in our atmosphere, and exercise such a baneful, and often, fatal agency, on the functions of animal life; are considerations which would almost warrant us in pursuing the enquiry here, could we hope to demonstrate the mode of operation, or the uniform agency of these deleterious gaseous bodies on that beautiful and wonderful piece of mechanism, the human frame.—But, alas! we can only speculate, instead of demonstrate. We can only reason, by analogy, from what we know of these gaseous substances, in their more concentrated form, as to what may be, or ought to be, expected from their action, in a diluted or attenuated state.

Hence, we know that carbonic acid gas will destroy life, on being inhaled a few times into the lungs. Therefore, we say, the smallest portion of this highly noxious gas must be, to a certain extent, deleterious.

Sulphurous acid gas is equally fatal to animal life; producing that peculiar odour, and suffocating or spasmodic effect, which is occasioned by the common operation, burning brimstone on a match.

Nitrogen gas is also incapable of supporting animal life, until it becomes mixed with one-fifth of its volume of oxygen—or the elements of common air. But there exists this peculiarity in the compound of nitrogen and oxygen—that its constituents have a greater mutual attraction (at the atmospheric temperatures), than any other gaseous compound with which we are acquainted. Consequently, while other varieties of gaseous matter are occasionally found in a state of mixture or mechanical suspension in the air, (and which may, *perhaps in every case*,—be absorbed or withdrawn, by applying certain other substances which have a greater attraction for the specific matter)—the atmospheric compound itself appears to resist effectually all decomposition or reduction, from any of the

ordinary processes of nature. It retains invariably its respective proportions of the two elements, (4 nit. and 1 ox.) at whatever altitude in the atmosphere it has been examined, or from whatever part of the world it has been collected for examination, by the usual chemical tests.

Hydrogen gas is also incapable of supporting life; though not so immediately fatal as the preceding gases. We indeed know very little of the effects of pure hydrogen. It however appears to be the grand agent or menstruum, in which most other deleterious gaseous matter is held in solution, when they are found mixed with the atmospheric air. Thus hydrogen and nitrogen, though in their separate state possessing neither taste nor smell, yet when combined, they produce the remarkable compound called volatile alkali; which, as we have before stated, consists of three parts (by measure) of the former, and one of the latter.

Now as we know this compound gas is ab-

sorbed by water with great avidity—in the enormous proportion of 460 : 1—it affords us a beautiful illustration of the salutary agency of water in the grand economy of nature.—It has been sufficiently shewn already, that, if any considerable portion of ammoniacal gas were allowed to remain, for any length of time, in the air we breathe, it would inevitably debilitate, if not destroy the animal functions. The extreme lassitude experienced by those who have been exposed to a depraved atmosphere for many hours together, being well known to every one. The Great Author of our existence has, therefore, beneficently supplied us with an immense omnipresent agent, capable of absorbing, probably, all the gaseous matter of this kind which can ever be developed, by the decomposition of animal and vegetable substances.

This absorption of ammonia by water (which may be taken as a thing proved, and incontestible), during the changes of matter by the ordinary operations of nature, is, moreover,

capable of easy explanation on the principles of chemical attraction.

The composition of water has been demonstrated, by the most profound chemists of Europe, to be 88 parts (by weight) oxygen, and 12 of hydrogen*; or, (according to the beautifully simple doctrine of chemical equivalents by Dr. Ure), 8 oxygen and 1 hydrogen.

From the same able authority, supported also by the profound M. Lussac, we are informed, that ammonia consists of .972 nitrogen, and .208 of hydrogen; or in the proportion of 4.7 of nitrogen to 1 hydrogen, by weight: though, in volume, as 3 of the latter to 1 of the former.

Now the alkaline principle, or that property which is known in chemistry as the *negative* of acidity, being proved to exist in such a remarkable degree in the compound gas called

* For the sake of simplicity, in a popular work like the present, it is thought best to omit fractional parts altogether, where practicable.

ammonia, whilst water must be considered (notwithstanding its apparent neutrality to our organs) as a highly oxidized hydrate;—it is perfectly natural that a very powerful degree of attraction should exist between these two substances. And we accordingly find in experiment, that the instant volatile alkali is liberated in the atmosphere, if water be present, it seizes on the gas with the greatest avidity, and will continue to do so as long as this gas is given out; or until the water become saturated: when the water will, in fact, become de-oxydated; or, in other words, have its oxygen so much overpowered, as to render the liquid altogether alkaline. Such is, in reality, the compound called "spirits of hartshorn" of the shops; or water highly impregnated with ammoniacal gas.

That this process is continually going on, with more or less activity, in the vast theatre of nature, cannot admit of a moment's doubt. And although we should not presume to consider every stagnant pond or ditch as analo-

gous to a series of Wolfe's apparatus for impregnating liquids with gas; yet we have thus endeavoured to shew, that something of this nature must necessarily take place during the evolution, recombination, and condensation of the various gaseous substances which are now known to exist in the grand chemical laboratory of nature.

We must, however, suspend our present excursions in these beautiful regions of chemical enquiry, and recommend the pursuit to more able, more profound travellers—while we return to the "matter of fact" points more immediately connected with our present investigation.

It has been already shewn, that the air of a room becomes vitiated both by animal existence and by combustion. And we have suggested the means of partially obviating the inconvenience, by exposing such liquids as are known to evince a powerful degree of attraction for these noxious gases.

But, as it has been a maxim, from the time of Hippocrates—"that it is better to prevent than cure"—we shall endeavour to point out the necessity of attending to the more perfect *ventilation* of dwelling-houses, or other buildings, where a considerable number of persons assemble together; as a duty incumbent, not only on those who have the immediate superintendance of such houses; but also as it regards the health and welfare of the community in general.

Though the latter consideration is one of remote interest with the majority of mankind; yet it would be easy to shew, that in some cases, but a few stages exist between our own individual welfare, and that of the bulk of the community. For example,—in case of any epidemic or dangerous class of fever existing in a given district, we may unconsciously be the means, not only of taking the contagion ourselves, but also of communicating and extending its ravages to other districts; if

either ignorance, or a want of common precaution places us in contact with such contagion.

Whatever may be the specific matter by which epidemic diseases are engendered; or of those fevers which produce contagion, by the medium of the air; it has been universally found, that all such diseases are greatly aggravated by an elevated temperature and a confined atmosphere. Indeed there is great reason to believe that the majority of the diseases included under the head of nervous and typhus fevers, entirely originate from a want of ventilation in the air, and the want of cleanliness.

It is clearly proved that those towns, or suburbs of towns, which are allowed to remain the receptacles of filth or garbage of various kinds, are more subject to the infectious matter which produce the typhoid class of fever, than others which are regularly cleansed, and supplied copiously with running water.

The advantage of a considerable surface of

water in the environs of a large or populous town will therefore be obvious, on the grounds we have previously shewn—its absorbent qualities. But it is at the same time proper to remark, that such water should not consist of stagnant ponds, or basins. For in such case the evil would probably be greater than the benefit, from the noxious exhalations given out by such stagnant water, especially in the summer, or autumnal season. A river having a rapid current, is perhaps the best possible ventilator of the air. For it acts *mechanically*, in producing a corresponding current in the superincumbent portion of the atmosphere; whilst it acts *chemically* by absorbing the deleterious gases before mentioned.

But in districts which are not thus favoured by nature, with this spontaneous and ever-acting ventilator, it is incumbent on those who have the custody of the public weal—or who ought to include this among other points of internal police—to enforce measures for

preventing the exposure of any vegetable or animal substances in a state of putrefaction, to the contact of the atmosphere, in the vicinity of dwelling houses. The offensive effluvium alone of such substances is sufficient to justify severe vigilance in this respect. But the evil is often far greater, from the subtle and imperceptible agency of these deleterious gases in vitiating the air, and thus laying the foundation of a formidable class of diseases which prevail more or less through a whole district.

Cleanliness is therefore not only a private but a public duty. And although the peculiar processes or manufactures carried on in many of our great towns cannot altogether be suspended on any considerations of public health or the public convenience; yet the nuisance or inconvenience might be in many instances mitigated, if proper measures were adopted for preventing the disengagement of noxious matter in the atmosphere, or else for arresting its progress when so disengaged;

instead of allowing it to incorporate with the air, and insinuate itself into the dwellings and even the chambers of the inhabitants of such towns or districts.

CHAPTER XI.

PURIFICATION OF THE AIR, A PART OF INTERNAL POLICE.

As this part of the subject is immediately connected with the consumption, or prevention of that vile nuisance, coal smoke; as well as the disengagement of the various putrescent effluvia from animal and vegetable decomposition. It is to be greatly regretted, that our police department should never have thought the subject worthy of their serious attention. The application of sumptuary laws would, certainly, not harmonize with the feelings and habits of Englishmen, generally speaking. But in proportion as it forms a part of the national character and the glory of

our countrymen, to submit patiently and even cheerfully to those regulations which are shewn to be enacted for the convenience and advantage of the community collectively; so would it be easy to apply and render effective regulations of this sort, if they were promulgated with the same impartial justice and liberal views as are evinced in many other departments of legislation, by the able statesmen who at present administer the executive authority under his gracious majesty, George the Fourth.

The subject of public health, is one which engages the most profound attention of the governments, in many of the European states. It may be necessary, or rather indispensible that such should be the case, in countries where private charities, or hospitals for the sick and infirm supported by the humanity of private individuals, bears no proportion to the extent of those establishments in this country! Yet the measure of charity can never be overfilled. We ought never to relax from the

exercise of that benevolence; or the administration of those powers which have been placed in our hands by our omniscient Creator for the wisest ends—that of the comfort and happiness of the human race *generally*.

The subject of health as a part of general police, has indeed, recently engaged the attention of some of the most able and scientific members of the medical profession of the present day; who have with great modesty, though propriety, strongly recommended this important subject to the especial consideration of the English government. It may therefore be hoped that many years will not elapse before some attention shall be given to a matter so vitally interesting to every member of the community in an equal degree.

To enforce our suggestions by giving one or two examples, from the metropolis.

The permission of numberless slaughter-houses in the very heart of the town ought surely to be immediately annulled by some competent authority, either general or local.

The condition in which many of those areas in London called markets, are often left after the transactions of the day, is a disgrace to the police regulations of any enlightened state like England. With regard to that intolerable nuisance Smithfield, its continued existence in the present state is not even attempted to be defended by any persons, except those persons whose cupidity impels them to sacrifice every other consideration, public or private. The animal matter deposited in this large area, when exposed to a powerful sun in the dog days of summer, cannot be supposed to be perfectly neuter or inactive, in the purlieus of that enviable district!

Covent Garden Market, also, though a refreshing and a beautiful scene, at five o'clock in the morning; yet at the same hour in the evening and for many hours subsequent, the olfactory nerves of the passenger demonstrate that *other* gaseous matter besides the aroma of flowers, is disengaging itself from the heaps of vegetable refuse which are allowed to re-

main after the bustle of the market is over. Surely this noxious matter should be removed immediately, or as early as possible; instead of lying exposed to an autumnal sun, and infecting the whole neighbourhood with its vile effluvia.

The peculiar effluvium of putrid fish may also be detected in various other districts of the metropolis besides that of St. Giles. It is not sufficient that such nuisance be kept out of view of the passenger in the larger class of streets; for in such cases this refuse or putrefactive matter is only removed from smaller heaps to accumulate in larger masses.

It is not an easy matter to inculcate habits of cleanliness or any other consideration as connected with health or public duty, in the wretched class of the inhabitants of the district before mentioned; but the powers with which the local police are already invested (by M. A. Taylor's Act) would go a great way to remove some of the nuisances of that neighbourhood, if the inspectors were to do their

duty. As we before observed, though these nuisances may be local, their effects may become very general. For who shall presume to say that a typhoid or a putrid fever shall be limited in the extent of its contagion!

Various other nuisances might be mentioned as existing in this great metropolis, which it would be in the power of an active branch of internal police to remove altogether or mitigate. But we cannot dwell on them here, farther than to recommend the subject to the especial notice of the heads of districts, as a serious and important branch both of public and private duty.

The prevention of that great nuisance, the evolution of immense volumes of coal smoke, might also properly come under the cognizance of an active police. Though this nuisance cannot be entirely removed whilst the present construction of our fire-places is allowed to exist; yet the great expence and difficulty to which individuals are subject, even in any endeavour to mitigate the evil by applying to a

jury, are such, as to make numerous manufacturers almost bid defiance to any question of public comfort, or public health, in the prosecution of their various processes where great quantities of fuel are consumed. There is no doubt that by a better construction of chimney flues belonging to close fires, or furnaces of all kinds, the major part of this nuisance might be abated. And so far as this goes it is the province of the local police to see these measures effected, not only for the comfort of the immediate district, but for the general salubrity of the metropolis or other large towns of the kingdom.

CHAPTER XII.

VENTILATION OF PUBLIC BUILDINGS.

The purification of the air in buildings of every description, either by ventilation or other means, is, however, an imperative duty on those who have the direction or management of such places. With regard to the *external* atmosphere, of certain districts, we have endeavoured to shew, that very strong presumptive evidence exists in proof of the supposition, that the origin of several febrile diseases is connected with gaseous miasmata in the atmosphere. But with respect to the interior of buildings, more especially edifices on a large scale, such as prisons, hospitals, ships, manufactories, or workhouses, which

usually consist of a numerous suite of apartments, the major part of which are occupied,—there can exist no doubt whatever as to the atmosphere of such buildings becoming speedily depraved and unfit for respiration, if it be not frequently renewed by proper ventilation. This important consideration has within these few years met with a certain degree of attention, though probably not to the extent which it really merits, from the valuable and patriotic services of the gentlemen who were delegated by the legislature to make a "Report on the State of Prisons" throughout the kingdom.

Independent of that unnecessary severity as to regimen, and the general want of attention to health among the inmates of many prisons, as they were formerly conducted: it can scarcely admit of a question that inattention to cleanliness, together with the want of proper ventilation, has proved the immediate origin of numerous cases of fever. And which diseases, in general, have not been sufficiently

investigated to ascertain the source, or at least, the probable source, from whence they have emanated.

Although it might not be possible at all times to trace the immediate source of so subtle an agent as gaseous miasma, especially when it is not distinguished by those properties which render it susceptible to our olfactory nerves; yet analogy will greatly assist us in all such investigations, if we take into view all the possible sources of deleterious matter which may exist in any given district or edifice.

We know that all organised matter, both animal and vegetable, when deprived of vitality, very speedily undergoes what is called spontaneous decomposition, or putrefaction. And this process is greatly accelerated both by elevation of temperature and a certain degree of moisture. Now, if any such organic matter be suffered to undergo this process even in its early stage, in the confined or badly ventilated apartments of those buildings which

have the doors and windows usually kept closed; it is quite obvious that the atmosphere of such apartments must be greatly vitiated. But in cases where no dead animal or vegetable substances are allowed to remain exposed, there will often be a most noxious exhalation of gaseous matter, as in buildings where a number of persons are confined in the same apartment.

This gaseous matter, as we have before observed, is not only disengaged from the lungs, but also from the skin, in great abundance. And, that it is not difficult to form a tolerable estimate of the peculiar nature of this transpirable matter, is proved by the exhalations which are disengaged from persons, who have been placed under either a course of mercurial medicine, or the use of sulphur in cutaneous diseases.

The gaseous matter given off by animals to the adjacent atmosphere, not only partakes of the nature of the aliment they make use of for diet, as we know from the effluvium of

onions, garlick, &c.; but it is greatly modified by the state of the fluids of each individual. Hence, it would follow, that the gaseous effluvium evolved from the lungs and the cuticle of those who have been confined to animal food (especially salted meat or fish) for a length of time, such as seamen during a long voyage, would be more insalubrious than the gaseous matter emanating from persons whose blood and humours are less vitiated. For it has been sufficiently proved by the most able medical men, and others who have the care and superintendance of hospitals, ships, and prisons, that a *mixed diet* of animal and vegetable substances is essential, in order to preserve the fluids of the human system in that state of equilibrio between acid and alkaline matter, which constitutes health.

The volatile matter which exhales from all the graminivorous genera of quadrupeds, is rather agreeable than otherwise; whilst the effluvium from the whole of the carnivorous class of animals, is not only more or less of-

fensive, but it is also very deleterious to respirable air.

It may be, therefore, justly inferred, that the peculiar character of the gaseous exhalations, both from the skin and lungs of animals, is, in a great measure, derived from the specific nature of their food: and as animal substances, during their decomposition, are known to give out a large proportion of alkaline matter in the form of ammonia, the transpirable matter from a number of persons collected in a single apartment, must vitiate the atmosphere of that apartment in proportion to their numbers, in the first place; and secondly, in proportion to the state of health or disease of their animal functions.

It would perhaps be impossible, in civilized society, to draw a distinction between those who are in the enjoyment of good constitutional health, and others whose constitutions have been vitiated and the mass of fluids depraved, either by hereditary taint, or chronic disease of long standing. But it can

scarcely admit of a question, that a given number of persons of the latter class would deteriorate the atmosphere of any confined apartment, to a greater extent in a given time, than an equal number of persons of the former class, owing to the exhalent gases being derived from a more vitiated mass of animal matter. In the general, or indiscriminate assemblage of individuals in large numbers, such as in theatres, lecture-rooms, chapels, churches, &c. it would be quite impossible to exclude certain auditors or spectators unless they produced what is called in our navigation laws "a clean bill of health;" but inasmuch as it is impossible, or if possible, quite invidious to exercise such precautionary measures against contagion in a free and civilized state of society, so is it the more incumbent on those who have the superintendence of all such places of assembly, to adopt every possible means in order to obviate the liability, or even the *possibility* of propagating epidemic or contagious disease through a whole

district, by employing the most convenient and effective modes for thoroughly ventilating such places of assembly. The discipline of hospitals, ships, and prisons, would, to a certain extent, admit of the distinction or classification we have referred to; more especially in the careful subdivision of those who are in the three states, of health, convalescence, or actual disease. For it is well known that the matter of contagion, in many species of cutaneous or other diseases, is evolved from persons who are far advanced in a state of convalescence; and this matter is also retained for very long periods in a state of active agency in the pores or interstices of clothing.

The utmost vigilance is therefore not only advisable in all such cases, but it becomes the sacred duty of those whose situation gives them a superintendence over considerable numbers of their fellow-creatures—as the masters of workhouses, governors of prisons and hospitals, masters of ships, managers of theatres, and the wardens of churches and

chapels—to adopt every practicable method of rendering the atmosphere of such places as pure as possible; not only during the congregation of great numbers of persons in the same apartment, but also after they have been dispersed.

During the presence of a considerable number of people in a limited area or covered building, the heat and aqueous vapour generated by the process of respiration, and the gaseous matter given off from the surface of the skin, will, together, have a tendency to render the air of such a building specifically lighter than that of the open atmosphere. And in consequence, the more offensive portion of the vitiated air will always ascend towards the roof or ceiling of the apartment. But there is also a considerable quantity of carbonic acid gas produced, both from the respiration of animals and the combustion of lights, which gas is perhaps more deleterious to animal life than the alkaline effluvium, or the nitrogen gas of the atmosphere; which

latter is in a measure, disengaged, by the union of the oxygen with carbon in the process of respiration. Now as the density of carbonic acid (as we have previously shewn) is greater than that of common air, as 1520 : 1000 ; it will be obvious that as the temperature of a room subsides to that of the external atmosphere after it has been vacated by a considerable number of persons, that the carbonic acid will have a tendency to occupy the lower parts of such room ; and will not be easily expelled from such situations without driving an artificial current of air through every part of the edifice.

The best proof and illustration of these matters that we can offer, is the well-known smell and noxious effects of the residuary gaseous matter from the burning of gas-lights. All artificial lights contaminate the air, but the rapidity of the combustion of gas in comparison with tallow or oil, renders the formation of carbonic acid much more rapid than with the latter substances. And wherever several

gas lights are used, (each of which of the ordinary interior burners is estimated to afford as much light as six candles, or a pound of tallow) the production of carbonic acid is so copious, that unless a strong current of atmospheric air be constantly allowed to sweep the apartment, the lower parts of the room will soon become exceedingly unwholesome.

In all public edifices, therefore, or places of resort for amusement—as theatres, concert-rooms, ball-rooms, or other places frequented only in the evening when artificial lights are employed, it is the imperative duty of the superintendents of such buildings not only to ventilate such places previous to the assemblage of the audience: either by throwing open the doors and windows, or by more effectual mechanical means. But after the audience has left such place, it should also invariably be submitted to thorough ventilation: for the purpose of driving off that carbonic acid, which would remain stagnate in the passages or lower parts of such buildings.

It is, indeed, well known to every one who has been in the habit of frequenting the theatres or public assemblies of any kind, that the atmosphere of the passages or lobbies, always seems more oppressive or "confined" than that which exists in the principal area of the building, where all the evil is generated. The reason of this is abundantly simple—the atmosphere of the principal saloon is diluted with aqueous vapour and a certain portion of ammonia, which invariably ascends towards the ceiling; while the dense carbonic acid will find its way out at the doors or lower apertures; or, will remain stagnant in the passages unless subject to a current of atmospheric air.

Though all gaseous matter is capable of mutual impregnation, and consequently a portion of carbonic acid will be held in suspension by every part of the atmosphere of an apartment where it is evolved in considerable quantity, either by the combustion of inflammable substances or the respiration of animals; yet

it will be always found, that the lower passages are more infested with this deleterious gas than the upper parts of the building; and more especially such places as the passages of theatres, which are not in immediate communication with the external air.

That carbonic acid, when mixed with atmospheric air and allowed to remain for some time in a state of repose, will always have a tendency to deposit itself in the lowest level of any edifice, is proved by the constant observations of miners and others employed in subterranean labours. For in the lower, and more remote galleries of a coal-mine, which do not easily admit of ventilation by the ordinary methods, the floor of the gallery is oftentimes infested with "the choke damp," so as to extinguish immediately a lighted taper or candle; whilst the roof will be so far free from the gas as to allow of respiration for a limited period.

The reverse of this takes place with regard to the "fire damp" or carburetted hydrogen

gas, which is so formidable an enemy to this most valuable class of labourers. Though this inflammable gas enters into more intimate union with common air than the "choke damp," yet whenever a considerable quantity of the inflammable gas prevails in the passages of a coal-mine, and for want of adequate ventilation is allowed to remain at rest, it will always occupy the upper part or roof of the gallery: and the workmen are in the practice of keeping their lights as low as possible, in order to prevent accidental explosions. But in spite of these precautions, and the use of that "invaluable legacy," the *safety lamp* of Sir H. Davy; accidents are occurring every year in some of the coaleries which are much infested with this gas, from the want of greater caution in exposing naked lights in situations where it is probable that an explosive mixture may exist.

Though the ventilation of mines is not immediately attached to our present inquiry; yet the vital interests which are connected

with the subject will be sufficient apology for a few observations in this place.

Whether we consider the carburetted hydrogen or inflammable gas of coal-mines, as gaseous matter disengaged from the interstices of the coal, when it becomes broken asunder by the operations of the workmen; or, whether it be the result of a partial decomposition of the coal, when its surface is exposed to the atmosphere—is of no moment in a practical point of view. It is probable that both these sources may operate in the formation of "fire damp;" though some coaleries are much more infested with this nuisance than others; which seems to prove that the gaseous or inflammable quality of the coal constitutes the principal source of the evil. Indeed it may be easily inferred that those varieties of coal which give out the greatest portion of flame, during its combustion, will be most likely to disengage part of its gas when broken down from the solid mass for the purpose of extracting from the mine.

And as our coal strata may be considered as so many basins of vegetable matter, which, at some very remote period, were covered by subsequent deposites of calcareous or aluminous strata; and which latter were again covered by a series of posterior strata; we may easily account for the condensation of the gaseous matter existing in coal, by imagining the immense (or rather inconceivable) pressure to which these beds of vegetable matter were subjected during the long series of ages they have been embosomed in the earth. That coal when broken down should liberate a portion of the gaseous matter which forms great part of its constituent elements, is therefore to be naturally expected; and, for the prevention of which, there is perhaps no remedy; with the exception of lessening the amount of the danger by extracting the coal in as large blocks or masses as possible.

There has been, indeed, considerable improvement of late years in the mode of working coals, so as to bring them "to bank" as

large as possible, and also to prevent the masses from unnecessary exposure to the weather or open atmosphere. This reformation in the former wasteful practice of coal-works, has been principally owing to that intelligent and opulent proprietor, Mr. Lambton. And as a proof of the benefits attached to this most rational mode of extracting coal and sending it to market, the present proprietor and his coadjutors have doubled their income from the increased demand for their coal in the London market, although there are one or two other coaleries on the north side of the Tyne which are working coal of a superior quality for durability.

But it is probably of far greater consequences to a numerous and valuable class of our fellow-creatures, the working miners— than to the pecuniary interests of the proprietors, that coal should not in any case be broken down more than barely necessary in the workings of the mine: in order to prevent every unnecessary disengagement of the inflamma-

ble gas. If the blocks of coal were conveyed as large as possible from the immediate "workings" into the principal gallery or railway; and there broken (if necessary) in order to fill the corfe-baskets, in which they are conveyed to the surface; great part of the evil would be prevented. For the inflammable gas thus disengaged in the principal railroad, will be so far diluted by atmospheric air, from the current which usually prevails, that no danger whatever of explosion need be apprehended. Until the gas forms about 1 : 12 of the atmospheric mixture, it is scarcely explosive: nor until the proportion of 1 : 10 is it highly dangerous.

But as it is utterly impossible under the best management, either to prevent the disengagement of a certain portion of this dangerous gaseous matter; or the formation of carbonic acid, by the combustion of lamps or candles, the respiration of men and horses, and the partial decomposition of the coal;—and as it is proved by the dreadful accidents

within two or three years past, that, even with the assistance of the safety lamp, these unfortunate men cannot be taught sufficient caution in pursuing their labours—it is imperatively necessary that the viewers or superintendents of coal-mines should employ every possible means for obtaining a thorough ventilation through their works.

The current of air produced by the large fires at the foot of the upcast shaft, is usually an effectual remedy against the collection of inflammable gas in the main passages. But where the workings are very extensive, it is quite impossible that the lateral passages—and especially those which are in actual work, and which form a sort of *cul de sac* in various parts of the coal-field—should derive much advantage from the current produced in the principal galleries. The very mode usually adopted to deflect the current of air through the passages, by what is termed brattices, is liable to great objection. For whenever a current of air impinges on any surface in a

perpendicular direction, great part of its velocity will be destroyed, and its effect, of course, proportionably diminished. The employment of wind-sails or air machines, for driving a current down the principal passages of a mine, is also ineffective where the works proceed to any considerable extent; as is proved by the occurrence of accidents even in coaleries which are, in the general sense, well superintended by the overmen and viewer.

It appears, however, that nothing short of an adequate supply of common air, carried into the immediate workings of a coal-mine, can ever effectually prevent the liability to accident. It would seem, that such an object would be easily attainable by having a series of pipes connected to a wind engine, or an air-pump attached to the steam engine, and extended to the immediate vicinity of the workings. These currents of atmospheric air would not only dilute the inflammable gas as it becomes evolved from the coal, but it would, of course, expel an equal volume of the im-

pure atmosphere of the mine through either or both of the shafts.

As it is in most coaleries at present—if the descending current of air in the down-shaft, or the ascending current in the up-shafts, meet with any obstruction, (and which must be the case to a great extent) the ventilation of the works must be proportionably impeded. But if a small current of air were continually flowing into the parts of the works most likely to be vitiated, or where the excavation of coal is actually proceeding, it would not only prevent the possibility of an explosive mixture being formed in the works, but it would also afford an adequate supply of air for the respiration of the unfortunate men, who are often obliged to toil in a recumbent position for hours together, in an atmosphere where a candle will burn with difficulty, from the large quantity of carbonic acid which prevails.

We have previously shewn in a former chapter (on Respiration), the deleterious agency of

this gas on animal life, and the debility of the animal functions after being exposed for any length of time to its noxious influence. It need, therefore, excite little surprise that the brave, and otherwise hardy race of men who are employed in our coaleries, should exhibit such pallid or emaciated countenances, and, in very few instances, arrive at the average period of mortality; even when not prematurely cut off by the various sources of accident to which they are exposed.—We may, therefore, close this divergence from the immediate subject of our essay, by remarking—That if it be essential for the preservation of health and comfort to adopt every practicable means for ventilating or purifying *buildings* of all kinds from a vitiated or noxious atmosphere; it is doubly incumbent on those who have so great a responsibility on their heads as the superintendence and preservation of several hundreds, or thousands, of the most valuable class of labourers in our various mines—to neglect nothing that could enable

them to secure the lives or limbs of these men from the most formidable class of calamities; as well as to preserve their health, as far as possible, while pursuing such laborious, and at best, a most unwholesome employment.

To return, however, to the ventilation or purification of buildings from stagnant or vitiated air.

The quantity of atmospheric air which it is necessary to have displaced or renewed continually, in order to maintain animal respiration in a perfect state; has been variously stated by different authorities, and which have led to very anomalous conclusions with regard to the necessity of a given area being appropriated to a given number of persons in the construction of public edifices.

Mr. Tredgold, in his Treatise, has gone into this part of the subject at great length, and with considerable ability. He estimates the necessary supply of fresh air for each person at nearly 4 cubic feet per minute; which es-

timate is probably not incorrect according to the *data* on which he has proceeded.—Mr. Tredgold assumes, that we make 20 respirations in a minute, and inhale 40 cubic inches of air at each; consequently, that we pass through the lungs 800 cubic inches of air per minute. Now this calculation, though sanctioned by the experiments of many eminent chemists, must be taken with great latitude. For although a robust man will inhale 40, or when in exercise, 50 cubic inches of air at each inspiration; yet, in ordinary circumstances, a person will not respire above half this quantity. The demand for a rapid supply of atmospheric air in respiration, is not only governed by the active or passive state of the individual, but by the capacity of his lungs, and the state of health or disease of the respiratory muscles. Thus a person who labours under a lanquid circulation of the blood, would not require so rapid a supply of oxygen to the air cells of the lungs, as another whose constitution was more vigorous; on the

same principle precisely, as a slow fire in our domestic stoves does not require so great a supply of air, as another which is destined to produce a powerful degree of heat.

Mr. Tredgold, (with Dr. Thomson and others) estimates the aqueous vapour evolved from the lungs as equal to about 6 grains per minute; which is also very nearly correct, so far as it goes. But as this aqueous vapour is the immediate result of respiration—whether we consider it as the production of water, *de novo*, by part of the oxygen of the air uniting with the hydrogen of the system; or, by the aqueous matter of the lungs saturating the air employed in respiration—it will be obvious that the *quantity* of vapour will always be in proportion to the quantity of air taken into the cells of the lungs.

With regard to the quantity of aqueous vapour, or other gaseous matter given off from the skin, Mr. T. justly observes, that it has not been sufficiently determined to enable us to calculate how much the air of an apartment

would be vitiated from this source. But (as an average estimate formed from the experiments of the French chemists) Mr. T. supposes 18 grains of vapour to be given off per minute from the human skin. And consequently, when all these sources of depravation of the air become united, it would be necessary to change 3 cubic feet of air per minute for each individual in the room. To which is to be added, the deleterious effect of artificial lights on the air of a room—and which is further estimated by our author as amounting to one-fourth additional—or altogether, about 4 cubic feet of fresh air for each individual.

Now although it is perfectly right to err on the side of safety, more especially in the construction of *new* public buildings (to which object the estimates and calculations of Mr. Tredgold are more particularly applicable) we fear, in the ordinary intercourse of society there could scarcely be a single instance put in practice, of so large an allotment of space

for each individual as that he should be supplied with four cubic feet of atmospheric air per minute. In all public assemblies, such as courts of law, lecture-rooms, town-halls, or indeed, wherever general attention is directed to a given part or point of the area, the spectators will at all times crowd towards that point without regard to the proper proportion of air for respiration. Indeed the inconvenience arising from having an area larger than is required for the immediate purpose to which it is devoted, is fully illustrated by our great theatres, and by the too great extent of many of the more ancient churches and halls.

The magnitude of any building therefore, which, according to the mode of estimate adopted by Mr. Tredgold, should always be regulated so as to admit of *spontaneous ventilation*, at the rate of four cubic feet per minute, would, according to our belief, meet with considerable (and effective) opposition from the judges, barristers, or lecturers, or others who would thus become inaudible to

the greater mass of their hearers—while the latter will, in all cases, whatever may be the size of the room, crowd round the orator as near as possible, without regard to the temporary injury of their health by impure respiration. Notwithstanding theoretical calculations may thus demonstrate what *ought* to be the proportions of any building to contain a given number of persons for a certain period, without prejudice to their health: yet in practice, or in other words, the daily intercourse of society, such calculations can only amount to a very imperfect approximation.

With regard to the mode of producing adequate ventilation in any new edifice calculated for the assemblage of a large number of persons—the plans recommended and pursued by Mr. Tredgold are certainly the most consonant with scientific principles of any which have been hitherto adopted. This gentleman very justly recommends that in order to have the most effective ventilation of

large buildings, such as churches, chapels, halls, &c. the ceiling should terminate in a dome, or a groined arch, instead of being horizontal. For as spontaneous ventilation, like the ascent of smoke, depends on the relative specific gravities of the internal and external air; and as the vitiated air from animal respiration, perspiration, &c. at the temperature at which it is evolved from the human body, is considerably lighter than atmospheric air, it will always ascend towards the upper portion of the building, and would consequently find a readier exit into the atmosphere through an aperture in the apex of any conical or arched roof, than it would through four apertures of the same aggregate area in the four corners of an horizontal ceiling.

This plan of constructing ceilings is not only the most conducive to good ventilation, but it is also the most ornamental for public buildings of every kind, and it admits of a more elegant mode of preventing the return of a current of cold air (by the suspension of a ho-

rizontal plate immediately below the aperture) than could be adopted in any arrangement for an horizontal ceiling.

The mode of admitting atmospheric air by means of draft-holes, or hollow chambers in certain parts of the walls of large edifices, as recommended by Mr. Tredgold, is also judicious and perhaps incapable of any improvement. It is obviously preferable, to admit a certain quantity of atmospheric air—whether cold air, for the purpose of maintaining the ventilating current, or warm air, for heating the room—through a series of small apertures, than through one large pipe. And a sufficient extent of wire-gauze, as suggested by Mr. T., is perhaps the most convenient and elegant form that could be devised for the apertures of air pipes, in the interior of buildings.

But although Mr. Tredgold has left us very little latitude for improvement of the principles of ventilation, as applicable to the construction of public buildings, *de novo*; yet a vast variety of edifices now existing, and fre-

quently occupied by considerable numbers of people, such as assembly rooms, coffee rooms, lecture rooms, &c. cannot admit of any thing approaching to an adequate degree of ventilation, on his principles, without subjecting the proprietors to an expenditure for building or repairs, which they would in very few cases be induced to incur; more especially for an object in which their own immediate interests are not involved.

But with regard to private dwelling-houses—the mode of ventilation pursued by Mr. Tredgold is still more inefficient. Not that it would be inapplicable in the original construction of private houses of the better class; or where gentlemen build their own mansions. In such instances (making due allowance for the disadvantages which horizontal ceilings occasion) the plan would be capable of being extended to the major portion of the apartments of a large mansion.

It is, however, a most important object, to render ventilation available for all kinds of

edifices, as they at present exist, public or private. And it does appear to us, from an attentive examination of the subject, that no other plan is capable of producing this desirable object, under every variety of circumstances, but that of supplying the necessary quantity of atmospheric air by some *Mechanical means.*

Mr. Tredgold truly remarks, " that ventilation is most difficult to maintain, in close, still, and gloomy weather :"—he ought to have added, that *it is impossible* to obtain adequate ventilation under such circumstances, according to his system. For as the whole basis of spontaneous ventilation depends on the possibility, or impossibility, of producing a current in the air, it will be obvious, that when the exterior atmosphere is in a state of repose, and more especially when it is nearly saturated with water—that it will be difficult, or rather impossible, to create an adequate current for ventilation, when the temperature of the external and internal air is nearly the same.

Though public assemblies, in all edifices of moderate dimensions, will find the atmosphere elevated to a temperature usually beyond that of our average summer heat, or say, from 75 to 90 degrees, according to circumstances;—yet it will be found, that most of our parish churches—which have not attained the distinction of being a place of *fashionable* resort, and consequently are not too much frequented—will frequently contain an atmosphere many degrees colder than that of our summer season. The cause of which is obvious:—these edifices being constructed of massive walls, and usually kept shut up during the whole week, the exterior atmosphere cannot gain admission, so as to equalize the temperature.

The confinement of the air of churches in this manner, by the negligence of those who have the custody of them, deserves our strongest execration. For we are not only exposed to an atmosphere (on entering a church for morning service) frequently 10 or 15 degrees

in the summer months below that of the external air, but we are obliged to respire a portion of air which has been allowed to remain stagnant during a whole week; and often vitiated by the gaseous matter evolved from human remains!

The plan of depositing the dead in the interior of our sanctuaries, may be advantageous to certain parties who sell these privileges to the highest bidders; but it is certainly disgraceful to the internal police of any country, to permit the existence of so palpable, or at least, probable source for the production of a malignant class of fevers; in conformity to the monkish customs of our forefathers, or for the pecuniary profit of a few hundred of inactive, or rapacious clergy.

As it is a fundamental maxim of ecclesiastical law, not to commence in any instance the 'work of reformation,' lest it might endanger the whole fabric; it becomes encumbent on our civil directors, not to allow our spiritual guides to send us "to the tomb of all

the Capulets" before our proper time, by first poisoning us with the mal-aria of their freehold cemetries, and then pocketing a handsome fee for the honour of being deposited by our friends near the place of execution!—We say, reform the system of interment altogether. "They manage these things better in France."

With regard to the mode of ventilation recommended by Mr. Tredgold, it is evident that it could not be applied with effect in the case of churches, or in vaults, or other places where the temperature is lower than that of the exterior atmosphere. For we never can make a lighter fluid descend through one of greater density, except by mechanical means.

It is scarcely necessary that we should enter into any minute description of the various mechanical methods that might be adopted for ventilating the atmosphere of any building. The mode previously suggested for ventilating mines, would perhaps be desirable for an extensive range of buildings: especially if a

steam engine were attached to any manufactory adjacent, by which a large supply of air might be obtained at a very slight expence of power. For an air-engine, or air-pump, for such purpose, need not be made so as to work the piston air-tight in the cylinder; the value of a little air escaping, being much less than the loss of power which would result from friction. The foot of such piston may be also made of wood, and the area of any dimensions requisite, (there being little or no friction); and the length of the stroke also may be as great as the engine beam would allow. In this way an immense supply of atmospheric air might be thrown into a room, or suite of rooms, by having pipes regulated by stopcocks conveniently placed for the purpose.

In other situations, where a steam engine or other great power is not required, a *wind-fan*, such as is usually employed for collecting a blast for furnaces, &c. may be adopted; and the revolving motion given by a horse wheel; or else, for smaller houses, by manual labour.

By this method, an area of any extent may be ventilated with infinitely greater rapidity and effect, than by any arrangement for spontaneous ventilation, that could possibly be devised.

Mr. Tredgold very properly recommends, that the supply of atmospheric air should always be given from below; or at least that it should not enter the room near the ceiling or roof; as it would thereby produce a deflecting current or eddy, so as to retard the escape of the lighter, or, as he thinks, more vitiated portion of the air.

Where the ventilation is effected according to his plan, this precaution is, doubtless, indispensible, for the maintenance of the ascending current. But it is not quite so certain, "that the most vitiated portion of the air in crowded assemblies is confined to the ceiling, or upper portion of the room."

That the *aqueous vapour* and *ammoniacal gas* evolved from the lungs and skin, will ascend towards the ceiling in the first instance,

both from its high temperature and its specific levity, is undeniable;—but there is, at the same time, a considerable formation of *carbonic acid*, which, as we have previously shewn, must, from its great density, descend towards the floor.

Now as we know that a great portion of the aqueous vapour evolved in crowded assemblies, becomes deposited in the form of *water*, on the windows and walls of the edifice; and (as we have also shewn) that water will take up at least 460 times its bulk of ammoniacal gas—we may easily imagine, that the lower strata of air in such apartment will be equally if not more depraved, for the purposes of respiration, than the upper portion. For the latter will have deposited great part of the gaseous matter it contained in the form of water and ammonia; while the carbonic acid will remain behind in the gaseous form, unless (what cannot be provided in such cases) there be a large quantity of lime water provided; and even then the absorption would not be

sufficiently rapid to compensate for its evolution by respiration and combustion.

Now supposing this state of the case to be equally near the truth, as that the upper portion of the room should be the almost exclusive receptacle of the noxious gaseous matter in a crowded room—it would not be of any importance in the *mechanical* ventilation of such apartment, whether the supply of air were thrown in from above or below. We should be inclined to give the preference to the former mode, for the fresh air would enter in such case, in the immediate vicinity where it is most required—or near the heads of the audience. Care being taken, of course, to prevent the cold current from descending in a mass, by passing it through numerous small apertures, or wire gauze.

In this case the supply of air for adequately ventilating an apartment, or suite of apartments, need not be nearly so great as if it were allowed to enter at the lower part of the room. For in the latter case it would be

greatly vitiated, both by mixing with the carbonic acid already existing in the room, and also by contact with the skin and clothing, previous to its employment by the respiratory organs of the individuals present.

With respect to the escape of the vitiated air in these cases, no anxiety need be entertained, nor any peculiar arrangement provided. For whenever we throw in a given quantity of atmospheric air into any room, an equal volume will immediately find its exit, by the doors and windows; even if they were constructed or fitted much closer than they usually are, in our public or private edifices.

The refreshing or reviving effects of a moderate supply of fresh air in crowded apartments, as ball rooms, concert rooms, &c., are too well known to require specifying here. And we feel convinced that mechanical ventilation, judiciously applied, would not only accomplish this desirable object, without any risk whatever of producing the bad effects of cold currents of air applied partially; but

that *perfect* ventilation may be obtained by this method in places where the spontaneous mode of ventilation would be totally inapplicable; and what is perhaps of still more importance, that it may be extended or diminished at pleasure without incurring any expence in the construction or alterations of buildings.

Mr. Tredgold has treated the important subject of ventilation under all the separate heads or buildings to which it is applicable: and inasmuch as the magnitude of his arrangements as an architect would altogether be governed by the number of persons likely to assemble in any given area, this may be a necessary professional view of the subject. But it will be obvious, how much additional expence would be incurred by making arrangements for ventilating an area for the accommodation of a thousand persons, when perhaps the average number that would assemble in such places might not exceed one tenth, or one twentieth part of that number.

The consequences of such arrangements would also, be a great sacrifice in point of economy. For if a current of air were allowed to sweep through any building capable of ventilating it for a thousand people, it is evident that too great a portion of heat would be carried off in the winter season, when such an edifice only contained one tenth that number. The plan of Mr. Tredgold, therefore, though advantageous to a certain extent, and affording very decided advantages for increasing the salubrity and comfort of our public edifices; is, however, far less economical and capable of regulation, than the mode of ventilation by mechanical means: more especially as referring to the interior of dwelling-houses, and the smaller class of public buildings, in their present state of existence.

CHAPTER XIII.

THEORY OF THE CONSTRUCTION OF CHIMNEYS, AND OF SPONTANEOUS VENTILATION.

It is well known that the draught of air through chimney flues, and consequently the degree of heat which may be produced in any furnace, depends principally on the height of the chimney; but the exact principles upon which the draught of chimneys may be calculated, are not well understood even by our first mathematicians. They all indeed proceed upon the principle of the acceleration of falling bodies, and the usual theorems of hydrodynamics, but they vary very considerably in the application of them, as will be subse-

quently shewn by a comparison of the results deduced by several eminent mathematicians who have made this branch of practical science their particular study.

That these principles may be better understood by the general reader, it must be recollected that when a heavy body of any kind falls in vacuo by the mere force of gravity,

If the times of the fall be in seconds of an hour—1″, 2″, 3″, 4″,

The height, h, fallen through at the end of each time, will be in feet, (avoiding fractions) —16, 64, 144, 256.

Hence the space passed over in each successive second, was—16, 48, 80, 112.

And the successive difference of these spaces, or the velocity, v, acquired at the end of each second, and producing the acceleration of the descent during the next second, will be —32, 64, 96.

And the constant second differences, exhibiting the invariable intensity of the power of

gravity, g, producing the acceleration at the end of each second of time is always —32.

From considering these numbers, it will be seen that the velocity, v, produced by a given height of fall, or that which a body will acquire after descending freely through that height, will be equal to the square root of twice the constant intensity of gravity, g, multiplied into the height, h, of the fall, or in other words, the square root of 64 times the height, or what is equivalent, 8 times the square root of the height. So that if a body falls 16 feet, it will acquire a velocity, v, of 32 feet $= \sqrt{2gh} = \sqrt{2.\ 32.\ 16} = \sqrt{64.\ 16} = 8\sqrt{16.} = 8.\ 4.$

The generality of writers have founded their calculations of the draught of chimneys, on the compound ratio of the acceleration produced by the height of the chimney, and the difference of specific gravity induced on air by the action of heat.

Mr. Montgolfier was the first who consi-

dered this subject. He supposes the velocity of the draught to be equal to that, which would be acquired by a heavy body which had fallen through a space equal to what would be the difference of height between two similar columns of air, one external equal to the height of the chimney, and standing on a base equal in area to the narrowest part of the chimney; and the other column, of the same height and base while hot, but reduced to the temperature of the atmosphere.

Now supposing the most simple case of the air being heated, yet so slightly altered in its specific gravity, by respiration or combustion, that it is not worth while in practice to take any notice of this alteration, and that the room to be ventilated by an opening in its ceiling is a double cube of 27 feet, with a door or doors 7 feet in height; whence taking the half-height of the door as the average entry of the air, the height of the column of air, will be $27-3.5=23$ feet and a half, and let the supposed temperature of this room be 60

deg. Fah. while that of the external air is 40 deg. so that the difference is 20 deg.

It is well known that the densities of gaseous bodies are inversely as their expansions by heat. Hence, although it would be a work of much labour to investigate experimentally the actual density of the warmed air, and that of the external atmosphere, yet this can be readily obtained by considering the expansion which the air undergoes by taking the volume and density of the external air as unity. For as the bulk of any portion of warm air, is to the bulk b, of an equal weight of the external air, so is the height h, of a column of air, from the entrance to its egress to the height, h', of a column of heated air, of the same height and standing upon the same base, while hot, but reduced to what it would be if cooled to the temperature of the atmosphere. In Algebraic formulæ, $\div\ b' : b :: h : h'$, or in numbers adapted to this particular example, $\div\ 1\ \frac{448+60}{448+40}$ $(=1\ .\ 045) : 1 :: 23 : 5 : 22$ feet $\frac{487}{1000}$ths. Hence there would be a difference of 1 foot

$\frac{13}{1000}$ths, between the heights of the two columns of air; and of course, if this difference be multiplied by 64, the square root of the product will exhibit the velocity, v, with which the heated air will pass through the ventilating opening in the open part of the room; or in symbols, $\sqrt{64\,(h-h')}=v$. Now 1.013 multiplied by 64, is 64.832, the square root of which is 8 feet $\frac{32}{100}$ths, which is therefore the velocity for each second of time.

If the velocity thus expressed in feet, be multiplied by the area of the horizontal section of the ventilating opening, expressed in superficial feet, the product will exhibit the number of cubic feet of the heated air that will pass in a second of time; and this may be reduced to the equivalent volume of cold air, by calculating the expansion the air has suffered by heat, and dividing the cubic feet of hot air by the increased bulk which a single cubic foot of air would aquire by the increase of temperature. Or if the number of cubic feet of cold air which the room contains, be mul-

tiplied by the increased bulk which a single cubic foot would acquire by the increase of temperature, and the product then divided by the number of cubic feet of heated air which will pass in a second of time, the quotient will shew the number of seconds that would be required for the entire renewal of the air, and this may be further reduced by the ordinary rules of arithmetic, into minutes or hours.

On the contrary, if the number of cubic feet of air which it is necessary should pass in a second, in order to replace the air of the room in a given time, or to burn a given weight of fuel, be first multiplied by the increased bulk which a single cubic foot of air would acquire by the increase of temperature, and this product divided by the velocity, the quotient will shew the area in superficial feet, that the opening must have to fulfil this intention.

But when the air is much altered in its specific gravity by combustion, Mr. Montgolfier

thought this alteration of specific gravity should be made an *element* in the calculation.

Supposing then a furnace with a chimney, whose top is 40 feet higher than the average height of the opening to admit the air, and the heated air issuing from the flue of the chimney, of the temperature 120 degrees Fah.

In this case as the bulk, b', of any portion of the expanded air, as it passes out of the chimney, is to the bulk, b, of a similar weight of air at the temperature of the atmosphere; so is the density, d'', (or specific gravity of the air vitiated by combustion, at the temperature of the atmosphere), to the density, d''', of the same vitiated air, when heated to the temperature at which it issues from the chimney.

Then by a second proportion, as the density, d, of the atmospheric air, (which may still be best taken as unity) is to the density, d''', of the heated vitiated air, so is the height, h, of the chimney, to the height, h', of a co-

lumn of vitiated air of the same elevation while hot, and standing on a base equal to the horizontal section of the narrowest part of the flue, but reduced to the temperature of the atmosphere. From which latter expression, the velocity, v, may be found, as in the preceding case. Or, in symbolic notation, first, $\div\ b' : b :: d'' : d'''$, secondly, $\div\ d : d''' :: h : h'$, lastly, $\sqrt{64\,(h-h')} = v$.

Then taking b, as unity, b' will be 1.163; and as the density of air vitiated by the combustion of coals, d'', may be taken as 1.077, of course the density, d''', when thus heated, will be only 0.926. In the second proportion, taking d, the density, or specific gravity of the atmosphere at the temperature of the moment, also as unity, then the density, d''', just found, 0.926 being multiplied by h, the height of the chimney, 40 feet, the product will give h', the height of the required column of heated and vitiated air cooled to the atmospheric temperature, namely 37 feet $\frac{40}{1000}$ths, so that there would be a difference of

2 feet and $\frac{960}{1000}$ths, between the heights of the columns. This difference multiplied by 64, gives 189.44, the square root of which, 13 feet $\frac{91}{100}$ths, is, by this mode of calculation, the velocity of the heated air, in each second of time; from whence we easily find the area the chimney must have in order to pass a certain quantity of air in a given time.

In the article, Furnaces, in Rees's Cyclopædia, the writer (it is presumed Mr. Sylvester), gives the elements of a different mode of calculation, which he founds upon the difference between the specific gravity of the heated internal air, and that of the external atmosphere. But he refers the motion arising from a change of specific gravity by heating, to the case of two weights hanging over a pulley; whence, according to Mr. Atwood's theorem, if the difference of the specific gravity of the heated air and external atmosphere, be divided by the sum of the same, the quotient multiplied by the velocity which a body would acquire by falling freely through

the same height, will give the velocity with which the heated air will pass into the atmosphere; or, using the same symbols as before, $\frac{d-d'}{d+d'} + \sqrt{64\ h} = v.$

The writer before mentioned, taking the density of the atmosphere as unity, and considering the degrees of temperature by Fahrenheit's scale p, which are required to double the bulk or volume of any given quantity of air; the which, as he gives no example of his mode of calculation, he does not quote, but by which he no doubt meant 480 degrees. Then unity added to the quotient, obtained by dividing the difference of temperature by 480, will, he says, be the increase of bulk in the heated air, or in symbols $1 - \frac{t'-t}{p.}$ and its density, or specific gravity, d', compared with that of the external atmosphere, will be equal to 480 divided by the sum of 480 added to the difference of temperature; that is to say, to $\frac{p}{p+(t'-t).}$ Of course the difference of the densities will be equal to the quotient of the

difference of the temperatures divided by the sum of 480 added to the said difference of temperature, or $\frac{t'-t}{p+(t'-t)}$. and the sum of the density will be equal to the quotient of the sum of twice 480 added to the difference of temperature, divided by the sum of 480 also added to the difference of temperature, or $\frac{2p+(t'-t)}{p+(t'-t)}$. The difference of the densities then being divided by their sum, the quotient, which is equal to the difference of temperature divided by the sum of twice 480, added to the same difference of temperature, or $\frac{t'-t}{2p+(t'-t)}$ is the tendency to ascend; and this multiplied into the square root of 64 times the height, will give the velocity of the ascending current.

The above theorem, he observes, will require an equation for the friction of the tube, which will be very great in chimneys made of bricks, and from some experiments, he thinks that every increase of velocity may be lessened one half to reduce it to practice. For

the retardation by the friction, and the acceleration of the ascending air, are both in the same proportion; that is to say, as the square root of the height. But if the velocity is increased by increasing the temperature at which the air issues into the atmosphere, then the friction will be increased in a higher ratio, namely, as the square of the velocity; so that if the velocity be made twice as great by increasing the temperature of the heated air, the friction will be increased to four times as great as before. Hence the height of a chimney can increase the power of a furnace to a certain degree only, since the increase of the friction will, after a certain limit, prevent the acceleration of the current, and bring the velocity to an uniform motion.

In the case of a room to be ventilated, to use the same example throughout, then the difference of temperature, 20′, divided by twice 480 added to the same difference, 20 (or 980), gives for its quotient 0.204, and the height 23.5 multiplied by 64, producing

1504, its square root is 38.7. Now this quotient 0.0204 multiplied by the square root, 38.7, produces $\frac{78948}{100000}$ths of a foot for the velocity, exclusive of any friction.

The general results will be thus:—the difference of temperature 80, divided by twice 480, adding the same difference (or 1040), gives for its quotient 0.0769; and the height 40 multiplied by 64, producing 2560, its square root is 50.5: now the quotient 0.0769 multiplied by the square root 50.5 produces 3.88345: so that if we take half this number to make allowance for the friction, it will give 1 foot $\frac{94172}{100000}$ths for the velocity in a second of time.

These velocities are much less than those obtained by the calculations of Mr. Montgolfier. The writer takes no notice of the change of specific gravity produced by combustion; and in using 480 degrees there is an error, as the proper number is 448, as has already been shewn; but these corrections are easily made, if this mode of calculation is adopted.

The Quarterly Journal of Science, for April, 1822, contained an essay, by that eminent mathematician Mr. Davis Gilbert, on the ventilation of rooms, and the draught of chimneys, in which essay he grounds his calculations on the velocity with which atmospheric air would rush into a vacuum, or into any medium of less density than itself.

The velocity, v'', with which the atmosphere would rush into a vacuum, is supposed by mathematicians to be equal to the velocity which a heavy body would acquire from falling from the height, equal to what would be the height of an atmosphere exercising the same pressure on the earth as the present atmosphere, but of a homogeneous density throughout its whole height. The supposed height of this ideal homogeneous atmosphere is deduced by saying, as the specific gravity of quicksilver is to that of common air at the level of the sea, so is the average height of the column of quicksilver in the barometer to the height p, of an ideal atmosphere supposed to

be of homogeneous density from top to bottom. Hence if the average height of the barometer be estimated at 30 inches, the specific gravity of quicksilver, as compared with water, as 13.5 to 1; and water as 800 times heavier than an equal bulk of air; then 30 : 13.5. 800 = 324000 inches or 27000 feet.

Dr. Gregory (in his mechanics) estimates the height as 27818 feet, and Mr. Gilbert as 26058; variations arising from minute variations in the estimates of the specific gravities of quicksilver, water, and air. In consequence there is an equal variation respecting the velocity, v'', with which the atmosphere would rush into a vacuum, which from the preceding theorem respecting the acceleration of falling bodies, is equal to the square root of 64 times the height, or which is equivalent, eight times the square root of the height: Dr. Gregory making it 1339 feet, and Mr. Gilbert, 1295 feet.

In the following calculations Mr. Gilbert's own numbers will be taken.

When the atmosphere, instead of rushing into a vacuum, rushes into a space filled with rarefied air, then, omitting the consideration of the resistance which the atmospheric air would experience from the inertia of that in the vessel, and which it must displace in its motion, as the density, d, or specific gravity of the atmosphere is to its pressure, p', so is the density, d', of the rarer or expanded air to the force, f, with which the rarer air would rush into a vacuum, whence this force, f, will be equal to the product of the atmospheric pressure, p'', multiplied into the density, d'', of the rarer air; and this product divided by the density, d, of the atmosphere; or in symbolic language, $f, = \frac{p' d'}{d}$. The moving power then will be the difference between the pressure, p', of the atmosphere, and the force, f, or $p'-f$; and substituting its equivalent $\frac{p' d'}{d}$ for the unknown, f, the moving power will be $p' - \frac{p' d'}{d}$.

Now as the squares of the velocities of influx are as the pressures; the pressure, p', of the

atmosphere is to the force, f, (with which the rarer air would rush into a vacuum) as the square of the velocity, v'', with which the atmosphere would rush into a vacuum, to the square of the velocity, v''', with which the atmosphere would rush into rarefied air of the density, d', or in algebraic notation, $\div p' : p' - \frac{p'd'}{d} : : v''^2 : v'''^2$: and of course, if the pressure, p', of the atmosphere be taken as unity, this proportion is reducible to the equation, $v''. \sqrt{\left(1 - \frac{d'}{d}\right)} = v'''$. Or, the velocity, v''', with which the atmosphere would rush into rarefied air of any assigned density, d', is equal to the square root of the difference between unity and the quotient of the density, d', of the rarer air divided by the density, d, of the atmosphere multiplied into the velocity, v'', with which the atmospheric air would rush into a vacuum.

On the theory of Mr. Davis Gilbert, the rarefaction, b', or expansion of the air by the heat, and, g', the density or specific gravity

of the elastic fluid as compared with atmospheric air, being ascertained, the expansion, b, divided by the specific gravity, g', will give the density of the air within the chimney: and the tendency to ascend, will be equal to the difference between this density and that of the atmosphere multiplied by the quotient obtained in dividing the height, h, of the ventilating tube or chimney by the assumed height, h', of the atmosphere, supposing it to be of uniform density throughout. The square of this quantity $\frac{h}{h'} \times \frac{b}{d'}$ multiplied by the velocity, v, with which the atmosphere would rush into a vacuum, and divided by the square root of the density of the lighter air, will give the velocity: or in algebraic notation, $\sqrt{\frac{h}{h''}} \times v' \times \sqrt{\frac{d}{b}} - 1 = \frac{v'}{\sqrt{h''}} \times \sqrt{h} \times \sqrt{b'} - 1 = v$. And the velocity, multiplied by the density of the heated air, and by the section of the opening in superficial feet, will give the cubic feet issuing in a second of time, reduced to the same density as that of the atmosphere.

To find the expansion of air by heat, Mr. Gilbert raises the fraction $\frac{481}{480}$ to the power whose index expresses the difference of temperature in degrees of Fahrenheit's scale, which is easily done by a table of logarithms. In this mode of calculation he follows the usual opinion with regard to any assigned volume of air or gas being expanded $\frac{1}{480}$th part by one degree of Fahrenheit's scale.

In the case of the room to be ventilated, the height, h, of the ventilating column, 23.5 being divided by the height, h', of the atmosphere, supposing it to be of uniform density, 26058, gives 0.00901; whose square root, or $\sqrt{\frac{h}{h'}}$, is 0.030: the expansion of the air, or $\overline{\frac{481}{480}}\Big|^{20}$ being equal, according to Mr. Gilbert's mode of calculating it, to 1.0423. Then subtracting unity, $b'-1$ will be 0.0423, whose square root is 0.2056: multiplying therefore, the velocity, v', with which the atmosphere would rush into a vacuum, or $v'=1295$ feet, by the numbers just found, namely, 0.030, and

0.2056, the last product will be the velocity, v', equal to 7 feet $\frac{888}{1000}$ths.

This velocity multiplied by $\frac{b}{b'}$, or 1.0423, as above, will give the number of cubic feet of air, reduced to the same density as the atmosphere which would pass through an aperture of one square foot in a second, namely 8 cubic feet $\frac{221}{1000}$ths.

In regard to the ascent of air through the chimneys of furnaces, it being necessary to attend to the specific gravity of the air vitiated by passing through the fire, Mr. Gilbert thinks that for practical purposes, the specific gravity of air vitiated by combustion, being of the same temperature as the atmosphere, may be estimated at 1.0874, common air being 1.

Mr. Gilbert varies greatly from other authors, in estimating the expansion of the air in chimneys; for he measures it by the temperature of the hottest part of the fire-room. To exhibit therefore the extreme dissonance of his mode of calculation to that of others, it

is necessary to assume some determinate degree of heat as likely to be that of the fire-room of a furnace having a chimney of 40 feet in height. The heat of a common grate, being a bright red heat, cannot be less than between 750 and 800 degrees of Fahrenheit, and no great error can be committed in estimating that of a close furnace, at 1500 degrees, as is done by Mr. Gilbert himself.

Here the expansion of the air by heat, b', or, $\overline{\frac{481}{480}}\Big|^{1500}$ will be equal to 22.68, and the specific gravity of the air which has passed the fire, when cooled to the temperature of the atmosphere, d'', as stated in the preceding paragraph is assumed to be equal to 1.087, and the density or specific gravity, of the heated air, $\frac{b'}{d''}$, will be 20.87, from whence subtracting unity, or the density of the atmosphere, the difference of density, $\frac{b'}{d''} - 1$, will be 19.87, of which the square root is 4.457. The height, h, of the chimney (40 feet) divided

by h' the height of the atmosphere supposed to be uniform, and assumed as 26058, gives 0.001534, whose square root, $\sqrt{\frac{h}{h'}}$, is equal to 0.391. Now the velocity, v', with which the atmosphere would rush into a vacuum assumed at 1295 feet being successively multiplied by $\sqrt{\frac{b'}{d}-1}$ or 4.457, and $\sqrt{\frac{h}{h'}}$ or 0.391, the final product 225 feet $\frac{677}{1000}$ths expresses the velocity in a second. This velocity is therefore very considerably greater than is calculated by any other author.

Mr. Sylvester (in a paper in the Annals of Philosophy, June, 1822) refers to Mr. Gilbert's calculations, and conceives the principle erroneous, as it gives velocities far exceeding that of heavy bodies descending freely in vacuo; whereas the resistance of the medium must cause a retardation, and render the real velocity inferior to that of bodies falling in vacuo.

Mr. Sylvester assumes unity as the density, d, of the atmosphere at the given tempera-

ture, and finds the relative density, d', of the heated air by the expansion, taking the usual calculation of $\frac{1}{480}$th of its bulk for each degree, whatever might have been its initial temperature; and takes no notice of any change of specific gravity by combustion. The temperature, t, of the atmosphere, being taken as unity, that at one degree above, will, he says, be 1+0.00208; and that at the assigned temperature of the hot air will be 1.00208 raised to the power whose index is the difference of temperature between the two airs, or $\overline{1.00208}|^{t'-t}$. Then, since the densities of bodies are inversely as their volumes, the density, d, of the atmosphere is to the density, d', of the heated air, as $\overline{1.00208}|^{t'-t}$ to unity; or (in order to get the density of the atmosphere to be unity) as unity is to $\frac{1}{\overline{1.00208}|^{t'-t}}$ the reciprocal of $\overline{1.00208}|^{t'-t}$.—Hence the difference of the densities, or $d-d'$, will be $1-\frac{1}{\overline{1.00208}|^{t'-t}}$; and as the density, d, of the atmosphere being

unity, has no effect as a divisor; therefore, this difference multiplied, (as in the usual theorem for the acceleration of falling bodies) by the square root of 64 times the height, or its equivalent 8 times the square root of the height, will give the velocity. The expansion for one degree, 1.00208 is easily involved to the required power by the help of a table of logarithms.

In the case of the room to be ventilated—the difference of temperature being 20 degrees, the 20th power of 1.00208 is 1.0423, whose reciprocal is 0.95941, being the density, d', of the heated air: and the difference of density, $d—d'$, will be 0.00405. The height of the column of heated air, 23.5 multiplied by 64, produces 1504, the square root of which is 38.7; which, being multiplied by the difference of density just found, namely, 0.00405, gives 1 foot $\frac{61}{100}$ths for the velocity.

In the case of the furnace—the assumed difference of temperature being 80 degrees,

the 80th power of 1.00208, is 1.181, the reciprocal of which is 0.84674, and exhibits the density of the heated air; whence the difference of the densities will be 0.15326. The height 40 multiplied by 64, the product is 2560, whose square root 50.5, multiplied by the above quoted difference of temperature, produces 7 feet $\frac{7396}{10000}$ths for the velocity.

Mr. Tredgold, in his recent work, has given us some new theorems for the investigation of this practical question; but he has rather retarded than accelerated the enquiry, by the elaborate *formulæ* he employs in his calculations. The power of the ascending current Mr. Tredgold assumes to be the difference between the weight of a column of external air, and one of internal air, when the bases and heights are the same; or, equal to the height multiplied by the expansion the air suffers from increase of temperature. And this expansion he calculates by dividing the difference of temperature, by the sum of the temperature of the heated air added to the constant num-

ber 450 : so that the force producing motion is expressed by him, algebraically, thus, $h\left(\frac{t'-t}{450+t'}\right)$.

The velocity, therefore, of the heated air passing through the pipes or chimney, is equal to the square root of 64 times this force, or in symbols, $\sqrt{\frac{64\,h\,(t'-t)}{450+t'}}$: so that if the height of the ventilating pipe or chimney be multiplied by 64; this product, by the difference of the temperatures; and if this last product be divided by the sum of the temperature of the heated air added to the constant number 450, the square root of the quotient will give the velocity, according to theory. But in practice, three eights must be deducted at once, on account of the retardation occasioned by the necessary contraction of the throat of the pipe or chimney, and the various eddies, bends, or changes of direction, in most chimneys, will require another correction, so that for general purposes, one half of the

theoretical velocity may be assumed as that attained in practice.

Taking, then, the example of the chamber, its height 23.5 multiplied by 64, produces 1504, and this multiplied by the difference of temperature, namely 20, produces 30080 for the dividend, or numerator of the fraction. The temperature of the heated air, 60, added to the constant number 450, gives 510 for the divisor or denominator: the quotient of 30080 divided by 510, is 58.98; the square root of which, or 7.67, is the theoretical velocity; from whence deducting three eighths for retardation, the remainder, 4 feet $\frac{8}{10}$ths, may be taken as the actual velocity.

In the case of the furnace, the height of the chimney 40, multiplied by 64, produces 2560, and this multiplied into the difference of temperature, 80 degrees, produces 204800 for the dividend: the temperature of the heated air, namely 120 degrees, added to the constant number 450, gives 570 for the divisor; the quotient of 204800 divided by 570,

is 359.29, the square root of which being 18.9, is the theoretical velocity; from whence deducting one half, partly for retardation by contraction by the throat of the chimney, and partly for eddies and other similar obstructions, the remaining 9 feet and a half may be taken for the actual velocity.

The following comparative statement of the velocities of ascending currents, as calculated by these different writers, exhibits the most extraordinary variations between them.

	Ventilation of chamber per second.		Draught of furnace per second.
Montgolfier	8.32	—	13.91
Sylvester, in Rees's Cyclopædia	0.78	—	1.94
Gilbert	7.88	—	225.67
Sylvester, in Annals of Philosophy	1.61	—	7.73
Tredgold	4.8	—	9.5

From the vast discrepancy in these calculations, more especially when it is considered that they are the labours of very eminent mathematicians, it must be obvious how little we know of the real nature of the question.

It would indeed appear, that all calculations on the subject are nugatory, if we were to judge from the practical results which have hitherto been obtained from the enquiry. For if the actual *data* for the construction of a chimney for any given purpose, so as to produce the greatest possible effect with a given quantity of fuel, were capable of demonstration, *a priori*, and under every variety of local circumstances; we should, long since, have seen more judicious modes of employing fuel for manufacturing or domestic purposes; as well as a more effectual mode of getting rid of that worst of all nuisances in a populous town—the evolution of vast columns of smoke.

The question is, in fact, involved in so many liabilities to accidental or extraneous influence, as to reduce it to a mere practical question in a majority of cases. The species of fuel employed, and even different varieties of these species, makes an essential difference in the ascending current through a chimney

flue, as we shewed in Chapter IV. on Fuel. The temperature, and especially the humidity of the external air, has also considerable influence in modifying both the draught of a chimney and the ventilation of a room—as is well known to every common observer, by the brilliant combustion which our ordinary fires exhibit in frosty or dry weather; and, *vice versa*, whenever the atmosphere is saturated with moisture. The density or levity of the external air, and the lateral currents produced by the erection of contiguous buildings, also operate greatly in modifying the draught or ascent of smoke. And, allowing for theaccidental presence or absence of all these different points of local and ephemeral influence, it is not surprising that all attempts to reduce the question to mathematical demonstration should have hitherto proved abortive:—or, at least, should have left the subject in as much obscurity as ever, so far as human economy, or practical science, is concerned.

PART II.

CHAPTER XIV.

OF OPEN STOVES FOR RADIATING HEAT.

The Theory of combustion and respiration having been considered: together with the principles on which the construction of furnaces and other fire-places depend; we shall next endeavour to apply these Principles to Practice, by giving a description of the various stoves or other grates for domestic purposes that have been introduced to the public; accompanied by observations on the most eligible methods of economising fuel and consuming smoke in the various descriptions of air furnaces; and the application of warm air and steam for artificially warming buildings.

The general construction of the ordinary fire-places in England, are too well known to require any detailed description here. The principal error lies in the present construction of chimneys; which, together with the malformation of the fire-place renders the loss of fuel so enormously great, that, according to the opinion of Dr. Franklin, not more than a fiftieth portion of the heat generated, was rendered available for warming apartments, at the period he resided in England.

Though it must be acknowledged that many improvements have been made in the construction of stoves of various kinds since the time of Dr. Franklin, more especially since the general introduction of the Rumford principle of contracting fire-places; yet at the present day there exists a most extraordinary inattention to economy, even in the best kinds of domestic stoves used in this country.

With regard to the primary evil—the construction of the flue-hole or shaft of the chimney, the present generation of builders seem to be as unacquainted with the principles on which the ascent of smoke depends, as their predecessors were, two or three centuries back.

It is indeed a most extraordinary fact, that, during the splendid inventions and improvements in the useful arts and practical science, which have so greatly distinguished the present generation, that the principles on which this branch of civil architecture depends should have been almost entirely overlooked. The want of education in the major part of that class of persons who call themselves "builders," in the metropolis, and who erect nine-tenths of the lower class of dwelling houses in the environs of the town, totally disqualifies them from paying attention to any improvement in Principles. They content themselves with blindly following the working-plans of their forefathers, entirely ignorant of any other principles than those of erecting houses (or rather, of executing their task) with the least possible expenditure of capital: and then getting these fragile fabrics off their hands as soon as possible.

From such architects it would be vain to look for any improvement in the principles of practical science. But there are numbers of well-informed young men who are educated

for the profession of civil engineers, architects, &c. from whom it might be expected that we should derive improvements in the construction of our domestic edifices, so far as comfort and economy are concerned; though the rigid rules of professors of ancient architecture forbid them from attempting any thing absolutely new in the ornamental parts of building, without being liable to the charge of "want of taste."

Fortunately, however, matters of mere taste form but a small part of the interior construction of dwelling houses. General utility, or, as it is called more properly, economy, forms (or ought to form) the principal feature of such edifices. And, as we have previously remarked, the general construction of chimneys and our ordinary fire-places, are not only inconvenient in respect of comfort, but they contribute to waste an enormous quantity of fuel, and at the same time produce the intolerable nuisance, more especially to foreigners, arising from the great disengagement of coal smoke.

The grand defect of chimneys, as we have previously shewn, consists in the too great

capacity of the flue, in proportion to the extent of the fire; by which, the entire area of the chimney can scarcely ever become sufficiently warmed to facilitate the ascent of the smoke. For if the temperature of the smoke and warm air be not considerably higher than that of the external atmosphere, it will not make its exit with sufficient rapidity from the chimney top, but will deposit part of its carbon on the sides of the chimney, and will be liable to return again down the chimney shaft into the room, in case of any lateral current being produced by the opening or shutting of doors or windows.

Another cause exists in populous towns where buildings are closely crowded together, which tends to retard the ascent of smoke from chimney flues, from the inequality of height of the numerous chimney shafts. Those which are low, and, consequently overtopped by others, when the wind sets from particular points, are almost invariably liable "to smoke," as it is called, from the smoke being impeded in its ascent by the lateral currents of wind and eddies, occasioned by the chim-

N 2

ney shafts, or gable ends of buildings, in the vicinity.

Although this evil is not exactly ascribable to the ignorance of the builder, nor, in many cases, capable of absolute cure, yet it might be greatly mitigated, and, in some instances, nearly prevented, if such lower chimneys were constructed on better principles, so as to accelerate their draught. The first and most common remedy for this inconvenience was the application of a chimney pot, with the view, as it was supposed, of contracting the passage for the smoke. But so far from this being the case, the base of these pots are, in almost all cases, of greater area than the flue of the chimney; in proportion as the area of a circle exceeds that of a rectangle.

These chimney pots may, perhaps, from their conical figure, have some effect in deflecting a lateral current of wind from exerting its full effect on a column of smoke; and with this view, the French terminate the chimney-top by four flag-stones formed into a kind of mitre. But these applications have but little influence on the current of warm air in the chimney, though they have rather more

picturesque appearance than the conical earthen pots attached to the square shaft of English chimneys.

Another plan has been suggested for accelerating the draught of chimneys by contracting the throat (at discretion) by means of what is called a Register. That this invention answers the intended purpose, cannot be denied; and, on account of the neat or finished appearance which it gives to the upper portion of the fire chamber, these registers have become almost universally adopted in our better class of dwelling houses. But it would seem that the inventor of these register plates must have been interested in the consumption of coal. For it would be difficult to devise any more effectual way of carrying off the warm air of the room, and consequently, increasing the velocity of a cold current of air from the doors or windows, than the plan of the register stoves in general use. The whole of these stoves being constructed of iron, which is so rapid a conductor of heat, and being placed in a recess or niche, and in immediate contact with the wall of the chimney, the greater part of the heat from the back of these iron

plates will go up the chimney shaft; whilst that which would be radiated from the front part of the stove is counteracted by a powerful current of cold air from the doors and windows.

Whoever considers the subject for a moment, will admit that these results will inevitably take place in the use of register stoves of the ordinary construction; and that, in proportion to the *goodness* of their draught, so ought they to be condemned, so far as economy of fuel, and comfort to the apartment, are points worthy of consideration.

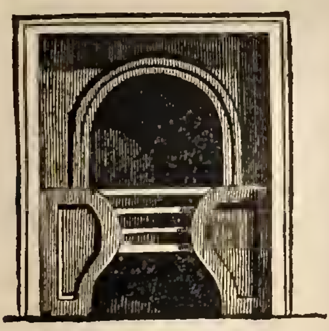
To begin with a description of the most simple and economical kinds of open stoves:—

Mr. Buchanan, in his "Economy of Fuel," p. 315, notices a mode of constructing the common fire places in some parts of Ireland, which appears well calculated to remedy the smoking of chimneys, and at the same time to lessen the consumption of coals.

The fire grate is wide but shallow, in order that it may throw out the greatest quantity of heat. The upper portion of the fire room, (*see wood cuts, figs.* 1 *and* 2), is partly closed

by an upright thin stone cut in the form of an arch. The back of the upper part of the fire room is formed of fire stone or fire brick into an oval niche, and a very small throat only is left for the smoke to escape up the chimney.

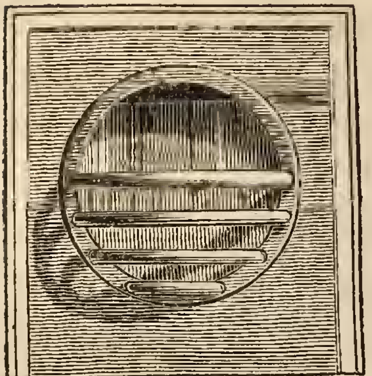
No. 1.



No. 2.

In some parts of England, as in the neighbourhood of Birmingham, the usual fire niche left in the sitting rooms for the insertion of a common grate or stove, is built up, leaving only a small opening for the passage of the smoke into the flue of the chimney; and the grate itself which contains the fuel projects entirely into the room. *(See figs. 3 and 4.)*

No. 3.



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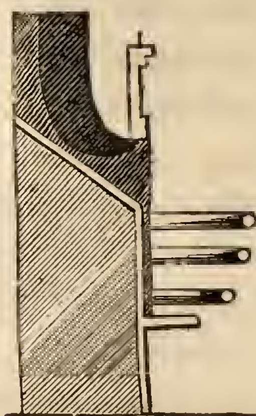


Neither of the preceding stoves will allow of the chimney being swept by boys; and therefore would not do well for London and its environs, where the fire-offices might object to their introduction, on the ground of the supposed increased hazard.

The next stove in point of simplicity, is the rude kind of American stove lately introduced into this country through the recommendation of that active and highly talented individual, Mr. Cobbett. These stoves consist of a large projecting cast iron hearth resting on brick-work, with the sides and hood, or head, also of cast iron; the fuel being burnt on three or four iron bars, resting on what are called dog-

irons in our old English farm-houses. That these stoves are far more economical than the ordinary grates, cannot admit of any doubt. But when good fires are kept, and the iron plates become much heated, they occasion that disagreeable and very noxious effluvium in the room which we call *burnt air*. They are also too inelegant in their appearance ever to become generally introduced in the better class of houses.

The most essential improvements that have ever been made in the construction of stoves, by one individual, are those we owe to Count Rumford. This indefatigable philosopher not only devoted the greater part of his life to this subject in all its branches, both theoretical and practical, for the advancement of domestic economy in his own country (Saxony), but Great Britain is also highly indebted to his persevering and fertile genius for his labours in this department of practical science.

The essential points in which Count Rumford improved our fire-grates, is that of contracting the area of the fire-chamber, (which used to be enormously large in our old fashioned English grates), and placing a flat surface in

each interior angle so as to reflect that portion of seat into the room, which according to the old square-chambered grates almost all escaped up the chimney. As these stoves are now in universal use in this country, and as the principles upon which they are constructed are so obvious and well known to every working bricklayer in the kingdom, any description of the mode of fixing these stoves would be quite superfluous. These stoves are indeed at present so fitted up by the furnishing ironmonger, as to render any skill in fixing them totally unnecessary. Plans and sections of these stoves are represented in Plate 1, fig. 1, 2, 3, 4.

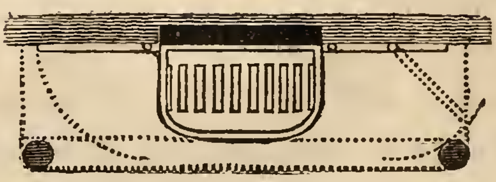
In fig. 2, the breast-work of the chimney, *a*, is rounded off in order to afford less obstruction to the ascent of the smoke; and when the chimney wants cleansing, the plate or flag-stone *b*, may be removed so as to open the aperture or throat of the chimney, and be subsequently replaced, after the operation.

In fig. 5, 6, 7, are plans and elevations of these stoves on the most economical principles suggested by Count Rumford. In fig. 5, a semicircular recess is cut out (or built) in the brick work, to the sides of which are sus-

pended the frame work or bars of the grate. A vertical section of this recess is shewn in fig. 6, and it will be evident from inspection that the arch of this recess will reflect a portion of that heat into the room, which would escape up the chimney shaft in the ordinary construction of fire-places. Fig 7, is an elevation of the back and sides of the stove, which is to be formed either of plate-iron, or slabs of firestone, or tiles.

The first and second figures of Plate 2, exhibit a stove with the ordinary cast iron back, and with moveable covings, either made of iron covered with black Japan varnish, or of polished steel. The jambs of the fire-room are removed, and it is open on three sides, being in fact only a plain wall, with a hood passing into the upright flue of the chimney. This hood is supported at each corner by an iron pillar, which carries the mantle.

The covings are moveable upon axes, and turn upon their upright edge nearest the fire. The axes are made to turn in an iron collar in the hearth, and at the top of the fire-room, so that they may be set at any required angle, or distance from the fire, as appears in the annexed plan.



By altering the angle in which the covings are placed in respect to the fire, the heat of the fire is reflected to different parts of the room; and by bringing them very near the side bars of the grate, the draught of the fire is contracted, and thereby increased.

In the third and fourth figure of the second plate are represented a fanciful contrivance for turning away the fire when the room is too warm. The fire is contained in an iron cage, with a solid bottom, the sides partly solid and partly formed of bars, and the top is formed of bars only; one of which takes out for the purpose of introducing the coal. The cage or grate is supported upon two pins, fixed in the solid parts of its sides; and moving on a swivel horizontally, which is inserted in a hole in the hearth.

By this construction, the front of the fire may be turned up so as to throw its radiant heat up the chimney; or by turning the

whole apparatus round on the swivel which supports the cage, the front of the fire may be turned to the back of the fire-room, and thus, the far greater part of the radiant heat of the fire prevented from coming into the room.

Another fancy stove is represented on the same plate, in figures 5 and 6. The fire rooms of the chimneys of two rooms being made back to back, are parted only by an iron plate moving on a vertical axis, turning in the hearth, and in the partition wall of the two rooms. On each side of this back plate are affixed bars to form a grate, in one of which a fire being made, should it render the room too warm, a slight pressure will turn it on its axis, and thus remove the fire into the other room, and substitute the empty grate in its place.

About two years back a patent was obtained by Mr. Cutler, an eminent stove-grate maker in Great Queen Street, for an improvement in register stoves; so as to enable the greater part, if not the whole of the smoke to be consumed. A full description of this invention was given in that useful weekly pub-

lication, "The Mechanics Weekly Journal," for Feb. 3, 1824. As this invention has been altogether laid aside, in consequence of a contested law-suit respecting the patent right of the inventor; and from the stoves not being at all likely to be generally adopted, on account of a certain heavy or clumsy appearance as a drawing-room stove; a brief description is all that can be necessary here.

These stoves were made on a similar construction to the general forms of register stoves, with the exception of the apparatus for supplying the fire with fuel. Instead of throwing on coals at the top of the fire in the usual way, the fire was supplied with coal from beneath. For this purpose a box, formed of iron plates, was suspended by chains attached to each end, which chains were coiled round the spindle or axis of two wheels placed in the interior of each side of the stove. These axles were turned by a winch, and a bevelled pinion, communicating to a toothed wheel. In order to use this stove the magazine of coals is to be filled in the morning by lowering it to the bottom of the ash-pit, and lighting the fire. The fresh

coal as it becomes successively ignited from above, will thus be compelled to pass its smoke through the body of the fire, and will consequently deposite the greater part of its carbon. But as the magazine of coals would prevent the necessary supply of air to maintain combustion, this object is provided for by having the sides of the fire-chamber formed of bars instead of being solid in the usual way.

Independent of the trouble attending the winding and unwinding this coal-box, it is very inelegant as an appendage to the better class of rooms, and would, therefore, not be likely to meet with the permanent patronage of the public, even if the patent right of the inventor had not been contested. For, it is verified by daily experience, that in this country more especially, utility alone will not recommend any invention to the favour of the public; unless it be also accompanied by an elegant appearance—or in other words—a conformity with established notions as to beauty or fitness, termed *fashion*. While the ornamental part of our dwelling houses is thus subject to the same dominion in matters of taste as the embellishments of our persons by

certain forms of dress; it is in vain to recommend utility or even economy to our upper classes of society, unless we consult the prevailing taste as to matters of elegance or uniformity.

Another variety of open fire stoves is coming into very general use for warming public offices, and other large buildings. The construction of the fire-grate has nothing peculiar in its arrangement, but is generally made on the common Rumford form with perpendicular covings sloping to the back. It is placed not under the flue of the chimney, but stands by itself in the middle of the room; and is closed immediately above the mantle with a flat plate, a passage for the smoke being left in the top of the back, which communicates with a flue placed behind the back of the grate, descending below the floor, and then carried horizontally to the common chimney.

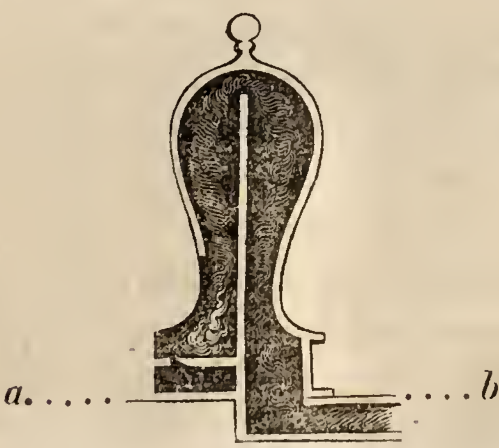
When good fires are kept every day in these grates with descending flues, the heat retained in the chimney causing a slight current even in the morning before the fires are lighted, will determine the proper course of the smoke;

but in other cases, it is rather troublesome to make it descend.

Sometimes in large offices, two, three, or even four of these fire-places are placed back to back, with a single descending flue between their backs.

The top of these fire-places may be made flat, and covered with a slab of marble, which being kept heated gently by the current of hot air, will serve to keep any thing warm that may be required.

In the galleries and halls of the better class of houses, these fire-grates with descending flues are frequently made of fanciful forms, as in this figure which sufficiently explains their construction. The line *a* . . . . *b*, shewing the plane of the floor.



CHAPTER XV.

RADIATION OF HEAT FROM CLOSE STOVES; OR CONFINED FIRE-CHAMBERS.

THE most economical mode of warming apartments, and if properly managed, perhaps the most salubrious also, is by means of radiating heat from confined fire-chambers. And the ordinary German stove, as it is called, is probably the most economical and simple that could be devised for this purpose.

In these close stoves the whole of the caloric given off by the burning fuel becomes dispersed in the air of the room, with the exception of what is just sufficient to carry off the smoke. And in case these stoves are properly constructed, the greater part of the smoke becomes consumed from the rapid supply of air which may be given to the ignited fuel.

In many parts of the continent where fuel

is scarce or expensive, these kind of stoves are in general use. For although the stoves of this construction which are usually employed in this country, are only calculated for heating workshops or manufactories, they are easily capable of being applied to culinary purposes, with the exception of that of roasting, which can only be performed by an open fire. The heat produced on the head or top of these stoves is indeed too great in many instances for the usual cooking operations. But if the top plate of such stoves be made of some slow conducting substance, such as a thick fire tile, or slab of marble, the heat may be regulated with much greater convenience, and economy also, than if these plates be made of iron.

The German stoves made in this country are also made of plate iron much thinner than is advisable. For when the fire is urged for a short period they speedily become red-hot, and in that case vitiate the air of the apartment with considerable rapidity. The scale, or rust of iron which forms on the surface, whenever that metal is exposed to a red-heat, being in fact an oxide of iron, which is produced by

the powerful attraction of iron for oxygen; and is therefore so far injurious to the atmosphere of such room for the purposes of respiration.

Even before iron becomes red-hot it serves to vitiate the air in a material degree, and communicates that peculiar odour before mentioned called "burnt air." But which odour is probably occasioned, not by any vapour emitted from the surface of the heated metal, as usually supposed, but from the nitrogen of the air (which becomes liberated by the absorption of the oxygen) acting on the surface of our bodies, and olfactory nerves, and uniting with hydrogen; and thus forming ammoniacal gas.—Whether this theory of the case be correct or otherwise, we know that the smell produced from heated iron is not only very oppressive to the respiratory organs, but it is evidently deleterious to animals exposed to its influence.

Another disadvantage attending the use of these stoves when the surface is greatly heated, is, that of depriving the air of the portion of moisture necessary for the respiratory functions. And this is more peculiarly injurious

to persons who are labouring under any catarrh, or other inflammatory disorders of the head or throat. In every case where these stoves are used for warming apartments, the plan which is adopted in many parts of the continent should be followed,—that of placing a shallow vessel of water either on the head of the stove or somewhere adjacent, in order that evaporation may furnish an equal quantity of moisture in lieu of that which the heat of the stove and apartment has dissipated. The neglect of this precaution will almost invariably produce a most distressing species of head-ache even to those who are the most robust; whilst invalids will feel the inconvenience in a variety of forms, sooner or later.

The close stoves used throughout the greater part of Germany and the north of Europe; instead of being made of iron, like stoves of every description in England, are constructed of masonry throughout; or of fire tiles, or porcelain plates embedded in mortar. Even the plates used for dampers, which come in actual contact with the fire, are seldom made of iron plate.

This substitution of *non-conducting* sub-

stances (or at least imperfect conductors of heat) in the construction of stoves and their appendages, is not only consistent with the soundest principles of economy, in the preservation of heat, and the more equable distribution of its advantages over any apartment or suite of rooms ; but it is infinitely more salubrious than the plan of warming the air of rooms by contact with the iron stoves or pipes so generally used in England. Though heated surfaces of all substances, except glass or porcelain-ware, serve to vitiate the air of a room in some degree, yet the rapidity with which iron produces this effect (from its violent attraction for oxygen) renders it probably the worst substance which could be devised for this purpose, with the single exception of zinc.

From the prevailing fashion in this country for polished steel or iron, in almost every department of our domestic appendages, (notwithstanding there is no country in Europe where it is more liable to the injury of rust) it would be in vain for any one to attempt the introduction of porcelain-plates, such as are in general use in Holland and the Netherlands, for facing the fire-grates or stoves ; or indeed

of substituting any other article than polished steel, for the better class of stoves used in England. The interests of the furnishing iron-mongers (to whom these matters are usually left by gentlemen furnishing their houses) may also operate in no slight degree in determining the prevailing taste for their own commodity, on the same principle as the currier recommended fortifying a town with leather*.

But if it be necessary, in obedience to the mandates of fashion, that we should retain polished steel for the *facing* of the better class of stoves, there is no reason, whatever, why the whole of the interior of such stoves should be formed of the same material,—unless it be for the purpose of carrying off the heat, evolved by the combustion of the fuel, by the most rapid means which could be devised!

There is even less apology for this wasteful practice being tolerated in our common stoves, than in those of the better kinds, for two reasons:—1st. Economy in the consumption of fuel is a far greater object with the middling

* Vide, Universal Spelling Book.

and lower classes of society, than an attachment to certain forms :—And 2nd. The black or cast iron stove grates carry off the heat with even greater rapidity than those made of wrought iron with polished surfaces.

It is true that a considerable portion of this heat is radiated into the apartment; but it is also true that a much greater proportion is carried up the chimney, by the injudicious construction of these stoves, and by the immediate contact of their cast iron plates with the brick work of the chimney.

These black, or cast iron stoves, moreover, radiate the heat into the room with too much rapidity when they become considerably heated, either for the purpose of comfort or economy; and as a natural consequence, they again cool with equal rapidity, whenever the fire be allowed to subside, or is neglected for any length of time. Thus we are placed between Scylla and Charybdis, between the extremes of heat and cold, during the winter season, in the space of a few hours, by the rapid conducting power of the materials of our ordinary grates, and the general bad arrangement of their respective parts. In addi-

tion to which, we experience the greatest of all evils, as far as health is concerned, in being placed near our open fires in a constant current of cold air on one side, and extreme heat on the other.

That we should be more liable to disorders, especially to those which originate from cutaneous obstruction, than any other nation in Europe, will thus admit of an easy explanation. And were it not for the general habits of cleanliness, for which the English are so eminently distinguished, and the improved state of medical science at the present day; the consequences of these cutaneous obstructions would be much more serious than they generally are. Though it is not easy to date the origin of those vast variety of chronic as well as acute diseases, which originate from obstructed perspiration;—either general or partial.

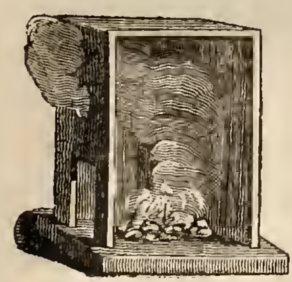
With regard to the prevention of these formidable evils, as far as may be, by a superior arrangement of our domestic fire-places;—it certainly does appear to be very possible to obviate great part of the danger, by having air-flues for the chief supply of the fire, car-

ried in from the external air to the foot of the stove, without passing through the room. If it should be considered too expensive to remove a small part of the flooring or side wall of houses now occupied, for the remote question of health, there is certainly no reason whatever why this arrangement should not be adopted in the construction of *new buildings;* except, that builders are not always obliged to be philanthropists. We have, moreover, such persons as district surveyors in certain great towns; but how far their jurisdiction may extend beyond that of providing for their families, has not been clearly defined by any of our voluminous statutes. Consequently the proper construction of chimneys, so as to prevent the waste of fuel, and the annoyance of smoke; as well as the formation of air or draught holes from the exterior of houses to the respective fire-places, in order to the increase of domestic comfort and health—are not included in the duties of surveyors, or their immediate paymasters—the speculators in new buildings.

To return, however, to the close-chambered stoves, generally used on the continent:—

There are several varieties of these stoves, though almost all on the same principle—that of burning wood in a confined chamber, constructed of fire tiles, flag stones, or other slow conductors of heat. The most simple variety of these stoves is represented in the following wood cut; which is merely a rectangular box

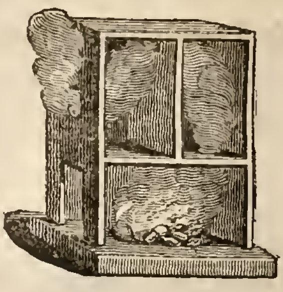
No. 1.



or chamber, with the front wall removed. This stove may be placed in a corner of the room, and supplied with fuel from without, the smoke also being allowed to escape externally. When the sides of this stove are sufficiently heated, the apertures may be closed by a piece of tile fitted to the openings, which prevents the heat from being dissipated

except by gradual radiation from the external surface. With a view to augment the heated mass, the stove is sometimes made with three

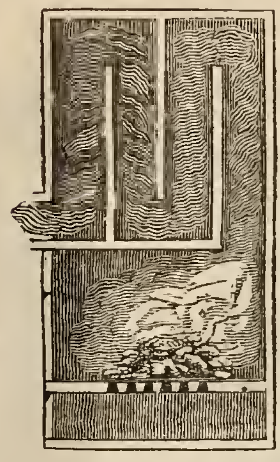
No. 2.



internal chambers of thin fire stones, as in figure 2. This arrangement retains the heat rather longer; but still the stove requires attendance.

In the preceding figures, the wood is represented as being burned on the bare hearth of the fire-room; but in the following figures the fire-room is parted in two by a grate, on which the wood is burned, as usual with coal. In No. 3, the chamber of the stove is divided into four, by three partitions, two directed so that the smoke and heated air is obliged to

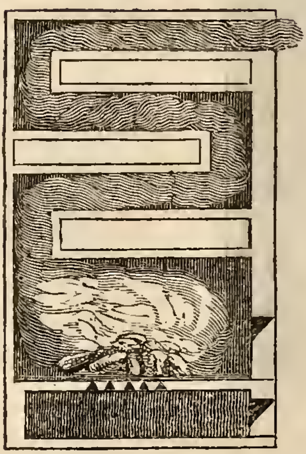
No. 3.



descend twice; and thus the current being retarded, it communicates more of its heat to the sides and top of the stove, and of course a smaller proportion of fuel is required to give a certain temperature to the room.

With the same view, the internal partitions are frequently made thicker than the actual sides; and the flues of the chamber directed either horizontally, as in figure 4, or vertically, as in figure 5. The partitions are made either solid or hollow, as they are represented in the figure. If they are made hollow, the ends next the room are sometimes left open,

No. 4.



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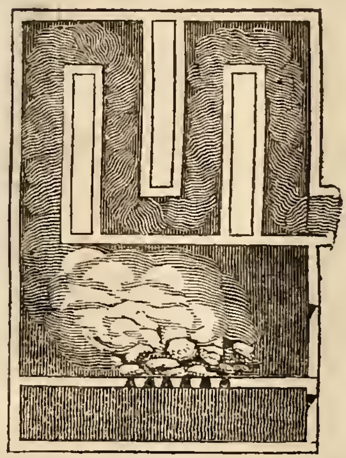
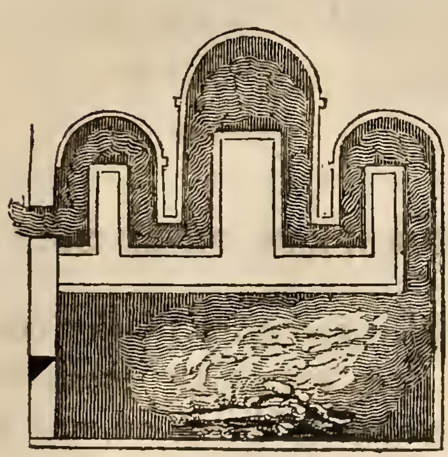


by which means the heating surface is increased; or they are closed with proper stoppers, in which case they may, if horizontal, be used as hot drawers, for the purposes of drying.

Although the general form of this smaller kind of German stove, is that of an ordinary chest of drawers placed in a corner of the room, so that the top of them are used in winter time as a drying place in the sitting rooms of the superior classes, they are made

of many other forms, as in the annexed figure 6.

No. 6.



CHAPTER XVI.

NORTH EUROPEAN, OR RUSSIAN STOVES.

In the colder countries of the north of Europe, the close stoves are made more solid than those already described, and more care is taken to get all the heat that is possible from a determinate quantity of fuel; especially as in many of the northern towns, a heavy excise duty is levied upon all the fire-wood that is brought into the town, which renders it necessary to be very economical in its use.

The figures in plates III. and IV. exhibit the most approved construction of these close stoves. As the air of the room is to be warmed solely by contact with the outside of the stove, it is not built close to the wall, nor immediately on the floor; but is raised a few

inches from it by low pillars, and is usually placed in a corner of the room; and stoves in the different apartments are so disposed that the chimneys may be joined in stacks as in our English houses.

The close stove whose sections are delineated in plate III. is of a more simple construction than that in the fourth plate, but proportionably less efficacious in heating the room. It is composed of a fire-room, *a*, *b*, fig. 1, 2, and 4, divided horizontally by a grate, both which cavities are accurately closed with doors, generally on one of the narrow sides, as represented in the plate; the door above the grate being double, to keep in the heat more effectually.

The smoke and heated air arising from the fuel burned on the grate of the fire-room, *b*, fig. 1, 2, and 4, passes through a slit in the roof of the fire-room, into the cavity, *c*, fig. 1, 2, and 3, immediately above it, and from thence by another slit, into a third cavity, *d*, fig. 1 and 2, the roof of which forms the top of the stove. These apertures just mentioned, are not placed one above the other, but are made on different sides of the roofs of the

cavities, as shewn at *c*, in the verticle section of the stove, fig. 1.

A square opening, *e*, in the upper part of the cavity, *d*, fig. 1 and 2, allows a passage for the smoke and heated air into a descending flue, *e*, *f*, fig. 1, 3, 4 and 5; and in consequence of the retardation this descent causes in the current of the smoke, great part of the heat is deposited on the sides of the flue. Having arrived near the bottom of the stove, the flue turns up, and ascends to near the top of the stove, as at *g*, *h*, fig. 5, 3, and 4. At *h*, a square opening forms a communication between the stove and the stack of chimneys belonging to the house.

The second variety of Russian stoves, sections of which are given in plate IV. are more complicated than those described in plate III. But as the principle of each is precisely the same, the description already given will enable the reader to trace the production and economical management of heat, without any description of plate IV.

Although the general construction of stoves throughout the north of Europe is never likely to become introduced into England for heating

dwelling-houses, while fuel is so abundant, and the national taste for open fires prevails; yet stoves on this principle might perhaps be applied with advantage in warming Conservatories or Hot-houses.

It would not however be necessary to suggest any modification here, with that view; as a subsequent chapter, describing several varieties of the Belper or Derbyshire stove, is more particularly applicable to the modes of heating buildings of all kinds by air-flues:—to which chapter we beg to refer the reader, and proceed to the mode of heating apartments adopted by the Chinese.

CHAPTER XVII.

CHINESE MODE OF HEATING APARTMENTS.

NOTWITHSTANDING the national jealousy of the government of the immense empire of China almost prohibits every species of intercourse with other nations; and the patriarchal system of government which has been adopted throughout the whole mass of society for a long series of ages, renders it almost impossible that these singular people should have derived any material improvements or discoveries in the arts from any other nations; yet the high state of perfection to which very many of the useful arts have attained, prevents us assuredly from considering them in the light of barbarians, or indeed, as any thing less than a most ingenious and inventive race of people, however much they may vary from

that conventional standard, which we, in our national greatness, term civilization.

In domestic economy, and in agriculture, especially, the Chinese are economists in the strictest sense of the word. And in some cases they extend this economy to limits which would not exactly square with our notions of delicacy. Nothing in China is considered useless, or is thrown away, from its minor value. And whether this rigid economy may be owing to necessity, on account of the extremely dense population of the country; or whether it be the result of deliberate study and experimental research, the fact appears unquestionable that in several departments of the operative arts and manufactures the Chinese afford us models well worthy of our imitation or adoption.

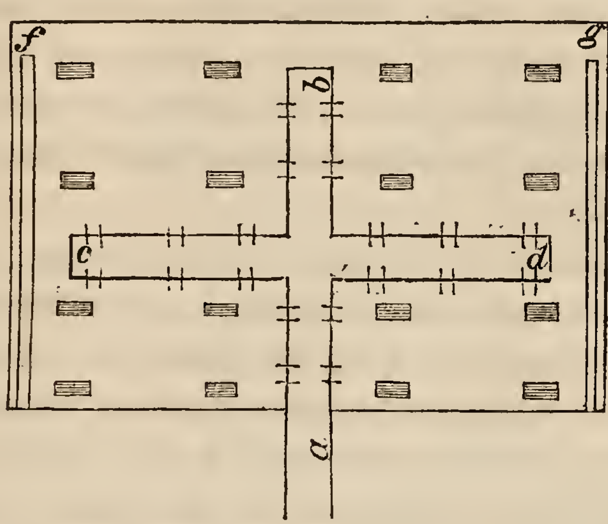
In the management of fuel for heating buildings and other domestic uses, they are admirable economists, according to the best accounts we have received of their internal arrangements. English travellers have indeed had very little opportunity of becoming acquainted with the domestic economy of the Chinese, owing to that commercial jealousy,

which makes them exclude our countrymen from visiting the interior of the country. The French missionaries of the last century are indeed the only authorities from whom we gain any information concerning the internal and domestic arrangements of these singular people. According to the account of Father Gramont (Phil. Trans. 1771) the climate of Pekin, where he was long resident, though 10 degrees farther south than the latitude of London, is considerably more severe in the winter season than the climate of England: the thermometer ranging from 9° to 13 below zero of Reaumur's scale; or from 20 to 30 below the freezing point of Fahrenheit.

In order to counteract this low temperature, the Chinese adopt the most scientific principles that could be resorted to,—that of building their houses with double walls, and having hollow flues extended beneath the floors; by which all the heat which is generated, is made available for warming the apartments.

In the better class of houses, the fire-place is constructed either against the exterior wall of the apartment to be heated, or else in an

inferior room adjoining: by which means the inconvenience of servants entering the rooms to superintend the fire, as well as the nuisance arising from dust or smoke is completely avoided. From the fire-chamber proceeds a main flue which is connected with the hori-



zontal flue, *a*, *b*, *(see wood cut.)* From *a*, *b*, another flue, *c*, *d*, proceeds at right angles to about three-fourths of the extent of the room. These flues are perforated with holes at proper distances in order to give out the heated air and smoke equally over the whole area of the flooring. Two horizontal flues are built in,

or attached to the side walls, as at *f*, *g*, in order to carry off the smoke into the external air, or into the flue of an upright chimney. The flooring of the apartment consists of flat tiles or of flag-stones nicely embedded in cement, so as to prevent the escape of the smoke or heated air from the flues beneath, into the room. These stones or paving-tiles resting on blocks of stone or bricks, may be made of any thickness required for the extent of the air-flues which are employed.

It must be obvious from inspection, that this mode of disseminating heat will be more economical even than the plan of the Russian stoves; whilst it disperses the heat more uniformly over the apartment, by its coming in contact with every part of the floor. These floors also being built of very imperfect or slow conductors of heat, and in the better class of houses, the paving tiles being made of ornamental porcelain ware, of considerable thickness,—when the floor has once become sufficiently heated by the flues, and the apertures of the main flues at the exterior being stopped, these porcelain floors will retain a sufficient

heat for domestic comfort for many hours, or rather during the remainder of the day.

It is perhaps good economy in such cases not to let the temperature get below a certain point, before a fresh portion of fuel is added to the fire; on the same principle as that it is a wasteful practice to allow the air furnaces of founderies, or other manufactories, to become extinct*.

The only objection that seems to present itself against the Chinese method of heating rooms, is that of the flues becoming choaked by the deposit of soot. This evil is, however, in a great measure, avoided, by the close eco-

* It appears, from the ruins of the Roman villas which have been discovered in England, and particularly from that described by Mr. John Lyster, in the Philosophical Transactions for 1706, vol. xxv. p. 2226, that these flued floors constituted that kind of hypo-caustum, which the Romans called fornax, or cænatiuncula hybernaria; except that the fire-room and chamber, or flue, was confounded into one; a deeper space being left between the two floors of tiles and the space heated by burning wood on the lower floor, the fuel being introduced by a door on the side. The ravages of the northern nations seems to have occasioned the disuse, in this country, of the Roman mode of heating rooms, and to have introduced our present ruder manner of effecting the same object.

nomy of this ingenious people. For instead of employing pit-coal of good quality, they make use of the inferior or small coal for this purpose; which refuse coal is mixed with a compost of clay, earth, cow-dung, or any refuse vegetable or carbonaceous matter, and then formed into balls, which are dried in the sun or open air. Independent of the cheapness of these fire-lumps or balls, they give out very little smoke during combustion, and consequently the flues are proportionably less liable to be choaked with soot. In some cases wood is employed for domestic fuel in China; but as they possess abundance of coal, and have a general communication throughout the kingdom, by water carriage; coal, or composts of coal and earth of various kinds, constitute the bulk of the fuel used in that country.

In the inferior class of houses, instead of having the stove built outside the house, it is constructed in a corner of the ordinary room. A pit being dug for the body of the fire-chamber and draught-hole, and the top or head of the stove is used for the different operations of cooking, or other domestic purposes.

That no portion of heat may be lost, or escape into the room by radiation, beyond what is requisite to maintain a given temperature, the Chinese place vessels of water on the head of the stove; which serves both to absorb and economise that heat which would be, otherwise, lost or waste; while it affords the necessary supply of moisture by evaporation, to preserve the atmosphere of a room always in a state of salubrity or of comfort. In this instance, therefore, (as well as many others in the useful arts) the English might take a lesson from these ingenious people; for a great portion of the inconvenience and oppression which we feel in our apartments during the summer season, or even in winter, when a considerable number of persons assemble together in rooms, artificially lighted, arises from the want of sufficient humidity in the air for the purposes of animal respiration.

We have already shewn in a previous chapter, that a few open or shallow vessels of water placed in crowded apartments, such as assembly rooms, lecture rooms, &c. would have a beneficial agency as an absorbent of part of the vitiated air, (ammoniacal gas): but it is

perhaps of far greater importance to health, to afford at all times an adequate supply of moisture to the air.

Although a very humid atmosphere—especially when accompanied by a low temperature, as during our autumnal months—is disagreeable, and productive of chronic diseases as well as "low spirits,"—yet the consequences of an excess of moisture in the air, are not so injurious to health as a deficiency of moisture.

Were it not for this important agency of water—designed by our beneficent Creator as the regulator of so many natural phenomena—we should not be capable of withstanding the scorching rays of the sun in tropical latitudes, nor the severity of the northern blast of winter. For in the former case, the evaporation of water following the elevation of temperature of the air, and (as we have previously shewn) the conversion of water into vapour requiring a prodigious supply of caloric from the air;—whilst a sufficient supply of water exists, the absorbtion of heat by the process of evaporation, will always keep the temperature of the atmosphere below that of the

human body, or 96° Fahrenheit. But in the interior of a large continent, or in districts abounding with vast deserts or sandy plains, the want of humidity in the air sometimes allows the thermometer to range from 110 to 120 degrees, in the shade.

Another proof of this beautiful agency of water, in moderating the extremes of temperature, is equally apparent in high latitudes.—The cold currents of wind blowing from the north and north-east during the winter, in our hemisphere, would be perfectly insupportable, if they were not mitigated in their severity by the aqueous vapour existing in our atmosphere. For during the process of congelation the aqueous vapour not only gives out to the atmosphere the vast quantities of caloric (estimated at 900° Fahrenheit) which is held in combination under the gaseous form; but about 140 degrees additional, while passing from the liquid (water) to the solid form of ice or snow.

It thus appears, notwithstanding our dislike or apprehension of the severity of snow storms, that they are destined to answer a most important purpose in the economy of

nature, by moderating the inclemency of the climate in high latitudes.

The importance of water, or rather of aqueous matter, in the grand external magazine called the atmosphere, will thus enable us to form an opinion of its value as a regulator in our domestic edifices. As each cubic foot of air (according to the accurate calculations of Mr. Daniell, in his valuable Meteorological Essays) at the temperature of 60° contains about 6.2 grains of water, when saturated with moisture; it will be readily seen, that a considerable supply of this aqueous matter will be necessary to maintain the air in a respirable state, whenever the temperature is much increased, and the air of the room become dried and vitiated by artificial lights and fires. The capacity of air for moisture being proportionate to the temperature, in an increasing ratio—a cubic foot of air at the temperature 84° will require 12.7 grains, or more than double the quantity of water necessary to saturate air at the heat of 60 degrees.

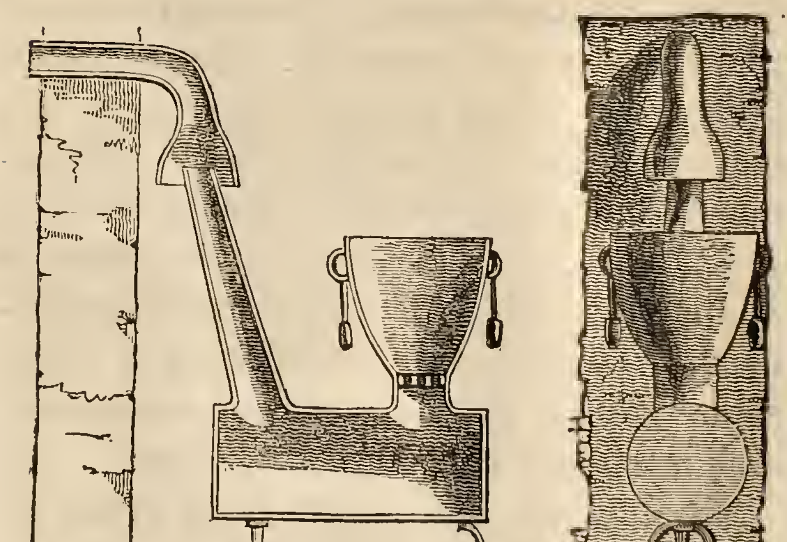
CHAPTER XVIII.

CLOSE CHAMBER AND VASE STOVES.

THE celebrated Dr. Franklin, among various other pursuits connected with practical science, devoted great attention to this department of civil and domestic economy. But although the general talent, or more accurately, the universal talent, of Franklin, must ever be acknowleged; yet it cannot be denied, that this great man was sometimes in the habit of availing himself of the discoveries or suggestions of others, and after effecting a slight modification in their arrangement, announcing such inventions as his own *ab origine.*

Thus, in the case of stoves or grates for more effectually economising fuel, many of the inventions described in his Essays were adaptations of the inventions of French or German philosophers.

In the middle and latter end of the seventeenth century, a M. Dalesme, a French engineer, invented a domestic stove or furnace, with the view of giving out nearly all the artificial heat to the apartment, whilst it was calculated to consume the smoke at the same time. The apparatus, which is the invention of Dalesme, improved by Dr. Leutmann, a German, is represented by the following wood cut. We should, at the present day,



perhaps, consider this apparatus rather rude; but as it obviously forms the basis on which

several later inventions have been founded, it is worthy of mention here. The vase, or fire-chamber, may be taken off, and filled with lighted charcoal or wood, and the drum, or lower chamber, and pipe, being then heated, by burning a little light wood or shavings, the vase is to be replaced; when, the air being only admitted at the top of the vase, will drive a current of heated air and smoke up the pipe, and into the flue of a chimney. It must, however, be evident, that some part of the smoke and vapour will ascend from the top of the vase into the room, and that it could only be used with any comfort with charcoal, or wood very well dried.

Dr. Franklin, in adopting this principle of constructing stoves, actually retained the vase-like appearance which Leutmann had given to the fire-place; and indeed, the only essential alteration he made in the construction was that of flattening Dr. Leutmann's drum, or lower chamber, into the shape of a hollow hearth, divided into flues; and not admitting any air to pass into the chimney beyond the fire. This last alteration renders his stove more truly a close stove than Dr. Leutmann's; but the pro-

priety of the alteration will be considered hereafter.

The general appearance of this stove, according to the modification of Dr. Franklin, is that of a cast-iron vase, standing on a pedestal in a niche or recess of the wall of the apartment, as represented in Plate V. figures 1, 2. The vase opens by a joint, *a*, fig. 2, in order to admit the fuel, which rests on the fire-bars, *b* : a plan of which is shewn, fig. 3. The height of the vase is from 20 to 24 inches, with an aperture at the top about 2 inches diameter for the admission of air. The lower aperture opens into the square box which forms the pedestal : the bottom of this iron box being furnished with bars, to allow the ashes to pass into the iron trough below, see fig. 4; or at *a*, in the horizontal section fig. 5. Beneath the pedestal are five (or more, if necessary) air passages, for more effectually disseminating the heat from the burning fuel. The front view of these passages being seen in fig. 1, and the section, fig. 5, *a*. *b*.*b*. *c*.*c*. These passages have a front wall or plate, something in the form of a fender, which prevents the smoke and hot air from flowing

into the room; but after giving out the greater part of its heat, it passes off by two holes, shewn in fig. 4, into the main flue of the chimney. Figures 6, 7, are representations of the cover to regulate the admission of air from the atmosphere into the vase, and to shut off the communication when requisite, from the vase to the air-chambers.

From the very nature of this construction, a current of air can only be produced through this stove (from above downwards) by heating the box below the pedestal and the air passages, previously to lighting the vase, which is to be accomplished as follows:—The communication with the air above being shut off, a few shavings are to be lighted in the center air-passage, the rarefied air and smoke finding its way through the other passages into the chimney-flue. After a current of air is thus created, and the lower chambers closed in, by lighting a fire in the vase, and opening the top, the supply from the atmosphere will continue the current downwards through the fire and air-chambers; so that little smoke will escape upwards. It is too troublesome an operation for domestics to superintend a stove of

this description. And as it is not calculated for burning coal, (both on account of the impossibility of preventing the disengagement of some of the smoke from recent coals into the room, and of the lower passages becoming choaked by the soot) though this stove is tasteful and elegant in appearance, it never would be generally introduced—even in the more ornamental parts of buildings, such as halls or libraries.

Dr. Franklin also availed himself of the labours of another eminent Frenchman, the Cardinal de Polignac, who, in the early part of the last century, published a treatise, entitled "Le Mecanique de Feu," under the assumed name of Gauger.

From this treatise, which contains many valuable suggestions on the best means of economising fuel, Dr. Franklin borrowed the construction of what he denominates his Pensylvania stove, both in compliment to his newly-adopted country, and more effectually to conceal the origin of its invention. As the principle on which this variety of stove is constructed, is very nearly similar to that of the Russian stoves already described, a

brief account of Dr. Franklin's adaptation is all that can be requisite here. Plate VI. figures 1 and 2, represent a front view of these stoves. Figure 1, having the front plate and screen removed, so as to exhibit the air-passages, *a.a.* Figure 3 shews the vertical section of this stove, while these air-chambers are represented above *h*, the current of air being admitted by a flue beneath the floor at *f*, and after passing through the iron chamber or box, escaping at the back part of the stove, and being prevented from ascending the chimney by the plate *g*, it is thrown out into the apartment. The fire being lighted at *a*, the smoke and hot air will pass down the middle passage *b*, and up the main flue *c*, provided the flue retains any heat so as to give a current in the first instance. The draught of the fire may, however, be increased, by allowing part of the air from the flue *f*, to escape near the front of the fire, and thus force up the current of smoke. The ground plan of this stove is represented in figure 4.

As the box or air-passages of this stove are formed of iron, and being in immediate contact with the burning fuel will speedily become

red hot, it is evident that the heated air which is thrown into the room from stoves of this construction, will have the disagreeable and insalubrious property of *burnt air*; which we have already stated as applicable to the common German stove made of iron plate.

Figures 5 and 6 are vertical and horizontal sections of the ordinary English grate, on the old square fire-chamber plan; only it is provided with a series of air-flues on each side between the iron plates of the fire-chamber and the jambs of the chimney. But the same objection that applies to the preceding form of stoves for burning wood, is equally applicable in this case. The air must necessarily be vitiated by coming in contact with red hot iron; while Dr. Franklin has not even made any provision for supplying the heated air with moisture after it has passed through a red heat! The pretensions of the doctor therefore as to any claim of originality of invention, either in the vase form stoves, or in those of the latter description are exceedingly slight; and had he not emigrated to a country where society was at that period almost in a state of infancy, and where his pretensions were con-

sequently not disputed, we should probably not have heard of *his* " Pensylvanian stoves." Dr. Franklin in some departments of science had original views; but from the specimens of his talent here represented, it would not appear that those views extended to the developement of any essential improvements in the construction of stoves or the consumption of fuel.

The celebrated French chemist, M. Guyton (de Morveau) was likewise guilty of attempting an improvement on the stoves commonly used in Sweden and throughout all the north of Europe; in order, like Franklin, to claim the honor of invention. The " improved" stove of M. Morveau is represented in plate VII., and is adapted for the use of wood fuel only, like the other stoves of this kind before described. Indeed the modifications in the construction recommended by this eminent chemist are in so slight a degree different from the stoves shewn in Plates III. and IV. as scarcely to deserve a separate plate. Fig. 1, Plate VII. is an elevation of Mons. Guyton's stove, and fig. 2 a section cut through the center: and fig. 3 a section cut through the

right side of fig. 1. Figures 4 and 5 are horizontal sections, the former cut through the superior portion, and the latter through the lower portion of fig. 1. *a*, fig. 1. is the enclosed fire-chamber, made of plate or cast iron, with air-passages on each side which alternate, as shewn at *b*, fig. 3, in order to bring the air more effectually in contact with the hot sides of the fire-chamber; after which it passes into the air-chamber, *c*, shewn in figures 1, 2, 3, where it is still further heated by the hot plate, *d*; from this chamber it flows through the two apertures *e*, *e*, into the apartment. These apertures being provided with plugs or stoppers to regulate the supply as may be necessary. The chamber, *f*, is a kind of warm closet built of brick or stone.

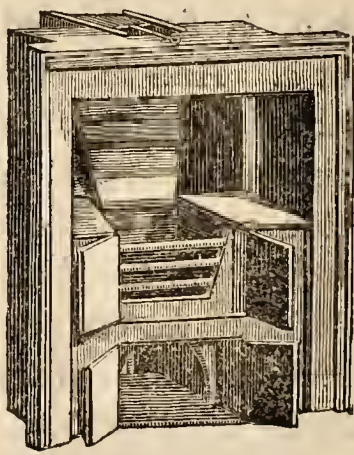
The fire being lighted in the space, *a*, figures 1 and 2, the smoke and hot air will ascend the back flue, *b*, fig. 2, and on arriving at the top of the stove will communicate its heat to the flues or hollow walls both in the front and down the sides of the stove, as shewn in the upper part of fig. 2, and in the sections at figures 4 and 5; after making this circuit the smoke escapes through a pipe at the back of

fig. 2, into the chimney-shaft. This pipe being closed by a damper when the wood has given out all its smoke in order to prevent the escape of heat unnecessarily from the stove into the chimney. The draught-holes for the air which is to be heated and subsequently thrown out into the atmosphere of the room, are shewn at *b*, *b*, fig. 1, and at the side view, fig. 3, at *a*. And the necessary supply of air for combustion of the wood is admitted through the small aperture, *b*, fig. 2.

As we before observed, the slight alterations of this stove from the plan of those used in the north of Europe, are not sufficient to entitle M. Guyton to the honor of an inventor. The only improvement is one which might have been naturally expected from such an eminent practical chemist—that of attaching a vessel of water to the stove so as to supply the heated air with sufficient humidity. But the iron plates of this stove, like those of Franklin, must greatly deteriorate the air for the purposes of respiration.

One of the best forms of arrangement which has been hitherto suggested for uniting the advantages of a close chamber-stove, with

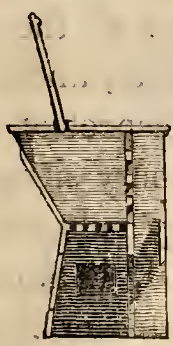
that of accommodating the English predilection for open fire-places, is the plan of a stove grate by Sir G. O. Paul, described in the xixth volume of Transactions of the Society of Arts, &c. and of which the following wood cut is a representation. The form is that of a com-



mon Bath stove, but with the hobs projecting two inches and a half before the front bars of the grate. Both the ash-pit and front of the fire-grate are closed with folding doors; there is also at top, an iron plate moving on hinges; which, when put up, serves as a continuation of the back to the stove, and when down, it serves as a cover to the grate, which is then completely enclosed. The smoke passes

through a notch in the back of the grate near the top. The iron cover, when down, may be used as a hot plate for culinary purposes.

Holes are left in the castings of the ash-pit to receive the mouth of air-pipes, either in the back, or on one or both sides, as circumstances may require.



At the top of the stove is a register sliding in groves, which, when pulled out, closes the opening from the room and space above the grate into the flue of the chimney, and opens that which communicates with the slit in the back of the grate. And when this register is pushed in, it shuts this communication, and opens that between the space above the grate and the chimney.

The draught-hole for supplying this stove

with air, when the ash-hole is closed, may be made to communicate with the ceiling of some other room, either below, on the same floor, or above that in which the stove is placed; or if the stove is used on ship-board, with the bottom of the hold.

It will be obvious, from an inspection of the principles of this grate, that when the doors are closed it possesses all the economical advantages of close stoves, and on opening these doors, the cheering aspect of an open grate is obtained. For ordinary sitting rooms, where part of the necessary culinary operations are sometimes performed, it also affords the advantage of warm plates or hobs, without any additional sacrifice of fuel. But owing to a certain heavy or clumsy appearance attached to the doors in front of these stoves, they have never been much introduced into use, notwithstanding the soundness of the principles on which they were constructed, and their economical advantages.

CHAPTER XIX.

OF THE VARIOUS KINDS OF COCKLE STOVES.

THE economical advantages to be derived from the use of confined fire-chambers in preference to open grates for warming buildings, have long been so well known, as to have induced several of our ingenious countrymen to adopt the principle of the close German stove in the construction of stoves for heating almost every species of buildings, with the exception of the domestic apartments of dwelling-houses. In the application of this principle however, a very different arrangement is necessary when coal is the fuel employed, instead of using wood. The latter substance (as we shewed in one of our early chapters) from its giving out a greater pro-

portion of hydrogen during combustion, the smoke may be conveyed off after passing through many circumvolutions in the flues; and without depositing any material quantity of soot in its progress. But owing to the superior density of coal smoke, and its liability to deposit its carbon, it is necessary to make it pass off at a higher temperature, and through flues of greater area than would suffice for the smoke of wood, peat, or coke.

The first person who made any material improvement in the close chambered stoves in England, was Mr. Strutt of Derbyshire; for the purpose of warming his extensive cotton-works more uniformly, and with greater economy than formerly. The first or most simple plan of these stoves, was that of making the fire-chamber of a cylindrical form, with a flat or dome-formed head, and a pipe leading from the upper part to carry off the smoke into a chimney-flue; like the old Dutch or German plate iron stoves. This iron fire-room, which from its figure has obtained the name of "the cockle," was then placed on a bed of masonry or brickwork, with a grating and ash-pit beneath, as represented in plate

VIII. fig. 1. At a given distance from the cockle, *a*, a mass of brickwork was built up, concentric with the cockle and its dome top, as at *b*, *b*, in order to allow a current of air, which was admitted by passages below, to come in immediate contact with the whole surface of the iron chamber and pipe. This air after being heated and consequently rarefied would naturally ascend towards the head of the stove, and pass through one or more apertures into the room required to be warmed; as at *e*. The fuel was supplied at the door *c*, passing down a sloping dead plate to the fire-bars. The ash-pit and draught-hole for the fire being shewn at *d*.

In order to bring the air in contact with a greater extent of surface; another form was given to the cockle by contracting its diameter and making it of iron pipe, bent into a serpentine form, as represented in fig. 2. The fire-chamber is formed by placing the grating near the lower part of the conical pipe, *a*, the opening to which, for the admission of fuel, is at *c*; another narrow opening is made immediately in front of the fire-bars, to allow the ashes to be cleared from the bottom of the fire.

The brickwork enclosing the cockle is built in the form of a parallelogram, the longest diameter at *b*, *b*, in order to contract the area of the chamber, and bring the air which is to be heated in more immediate contact with the surface of the cockle previous to passing into the room through the aperture, *e*, at the top. By this arrangement a saving of space is effected, which is sometimes an object in small apartments.

Another variety of these stoves is shewn in the horizontal and vertical sections, figures 3 and 4. The cockle instead of being cylindrical, is made of a rectangular form, having the top plates or head meeting in a sort of groined arch. The fire-room and ash-pit is similar to those of fig. 1, but the smoke and hot air after passing upwards and warming the top and sides of the cockle, is made to pass off into the chimney-flue through the narrow channel attached to the side opposite the fire, as seen at *c*, *c*, figures 3 and 4; by which means, it is presumed, less heat will be lost than when the smoke is allowed to escape near the head of the cockle. The air is admitted by three passages at the base of the

stove, shewn at *b*, *b*, *b*, fig. 3, and in order to prevent its escape into the room with too much rapidity, a few tiles or plates of iron are inserted in the brickwork, to retard its passage until it shall have been heated by coming in immediate contact with the sides of the cockle, previous to its evolution into the room or building, through the flue *a*, fig. 4.

A fourth variety of these stoves is shewn in figures 5 and 6 of the same plate. The only essential difference of which from the preceding, consists in the numerous apertures by which the warm air is allowed to make its escape into the apartment to be heated; and in having two passages for the smoke to escape into the chimney-flue, shewn at *a*, figures 5 and 6. In fig. 6 part of the apertures are supposed to open into a lower apartment; whilst a kind of dome flue carries the warm air from the head of the stove into an upper apartment.

The before-mentioned stoves are principally calculated for warming apartments or manufactories to a moderate degree only, or for personal comfort. But as many kinds of manufacture require a considerable degree of

heat for the purpose of drying goods, such as calico printers, dyers, printers, &c. a much greater heat is capable of being given to a certain quantity of atmospheric air by the following arrangement, *(See plate IX.)* than in those varieties before described.

Figures 1 and 2 represent front and side sections of this kind of stove. The cockle, or body of the stove, *a*, is usually cast in one piece, with the exception of the cover, which is made to fit on close. The vase rests on the fire-bars, shewn in horizontal section in fig. 4, where the ash-hole with its door, *d*, is shewn, and also at *d*, fig. 2. The opening for the supply of fuel is shewn at the door, *b*, fig. 2; and the flue for carrying off the smoke at *c*, of the same figure. The passages in fig. 1, *b*, *b*, *b*, *b*, are for admitting the air to be heated, after which operation it passes off into the room by the opening *c*, in the top; or through the lateral openings, *c*, *c*, in fig. 4. Fig. 3 is a horizontal section of the ash-pit, and two air-flues. The brickwork is built of considerable thickness round the cockle of these stoves, in order to prevent the escape of heat in the immediate vicinity of the stove,

and of course more effectually economising the fuel; as they are sometimes built in other apartments than that which is required to be heated. From the whole of the lower part of the cockle being the receptacle of the ignited fuel, it is obvious that its exterior will often be elevated to nearly the same temperature as the inside; consequently, a current of air passing over its exterior surface will become heated in a proportionable degree to the rapidity of its passage.

This method of heating air is undoubtedly the most economical which has been hitherto devised in this country, as all the disposable heat given out by the fuel (with the exception of what is necessary to carry off the smoke) is absorbed by the air in its passage through the air-chamber of the stove. And, although this mode of heating air is not exactly suitable for dwelling-houses or animal respiration, on account of the deterioration of the air by hot iron; yet in many operations of the arts, as for drying corn and other natural produce, as well as in various manufactories, it affords a most convenient and economical method of disseminating heat.

Another modification of this stove was invented by Mr. Strutt for bringing the air to be heated into a kind of focus, and thus making it come into closer contact with the fire-chamber.

Fig. 5, (Plate IX.) represents the cockle as a dome resting on a bed of solid masonry, in order to prevent the escape of heat. The air is admitted through numerous openings round the base of the stove, at *b*, *b*, and after passing over the surface of masonry, *a*, *a*, comes in contact with the head of the cockle; after which it escapes through numerous iron pipes into a main flue above the head of the stove as seen in fig. 5. Fig. 6, represents a very simple and economical stove on the principle of the lime-kiln. The body of the stove, *a*, may be constructed of masonry or brickwork, having an ash-hole and fire-bars; the latter of which is made to draw out by the handle, *d*. The fuel is applied at the top, which is closed by an iron plate or fire-tile, *c*, like the common air furnaces; the smoke and hot air passing up the flue into a chimney-shaft, at *b*.

Notwithstanding the obvious advantages in point of economy, from heating extensive cot-

ton mills or other manufactories, and warming hopitals, prisons, or other buildings where open fires would either be impracticable, or unsafe,—by means of the cockle stove, under some of the arrangements before mentioned: the plan was not sufficiently made known to the public, nor its economical advantages pointed out, until it was mentioned by Mr. Buchannan in his "Essays on the Economy of Fuel, and Management of Heat;" published in 1815. Since which period, Mr. Sylvester in his very able work, "The Philosophy of Domestic Economy," has materially called the attention of the public to the great importance of the question, by shewing the beneficial application of an extensive stove of this kind erected in the Derby Infirmary.

As this stove and its appendages may be taken as a model for the construction of all others for similar situations, (allowing for the extent of the building) the following description and plates, will, it is presumed, afford sufficient directions to the architect or builder employed in such work.

It is necessary that the area on which a stove of the following description is to be

erected, should allow of a subterranean passage being carried out and communicating with the external atmosphere, at some convenient distance from the building. In order to allow of producing a current of cool air for the purposes of ventilation in the summer season, as well as for the supply of the stove for warming the air of the apartments in winter. The stove should also be erected as near the middle of the area of the building as convenient, and be placed from 6 to 12 feet below the floor, in order to preserve uniformity as much as possible in distributing the warm air through the edifice.

A section of the stove erected at the Derby hospital, is shewn in Plate X, fig. 1; and a horizontal section of the same is seen in Plate XI, fig. 2. The cockle, *a*, (Plate X, fig. 1.) is made of a cubical form, with a dome, or rather groined arch top; about 3 feet diameter and 4 feet high; and is made of plate or wrought iron rivetted together like the ordinary boilers of steam engines. The smoke passes off by a narrow passage at the base of the cockle (as in the stoves before mentioned) and through the flue, *f*, or as seen in the

horizontal section, fig. 1, Plate XI. The brickwork surrounding the cockle, is built with alternate openings between the bricks (as represented in the side view, fig. 2, Plate X.) at about 8 inches distant from the sides of the cockle. Through these apertures, pipes are inserted (which may be made either of sheet-iron or common porcelain-ware) so as to extend within an inch of the cockle; (as shewn in the enlarged sections in Plate XII,) by which means, the air to be heated may be thrown near, or in immediate contact with the surface of the cockle if desirable. The horizontal partition represented at *d*, *d*, fig. 1 and 2, Plate X, cuts off the communication between the lower and the upper portion of the air-chamber. The arched openings in the lower half at *c*, *c*, and in the section, fig. 2, Plate XI, being the openings of the main air-flue leading from the exterior atmosphere. The fire-room and ash-pit, *b*, *b*, with their doors and fire-bars, are shewn in elevation, and horizontal, and vertical section, in figures 1, 2, and 3, plate XIII.

The inspection of the figures will shew that a quantity of air passing from the lower flues,

c, *c*, through the apertures beneath the horizontal partition, and coming in immediate contact with the body of the stove, must find its way into the upper air-chamber, *e*, *e*. through the numerous apertures or pipes in the upper division, by which circuit its velocity will be sufficiently retarded to obtain the necessary elevation of temperature from the heated cockle.

But in order that the air may not be injured for the purposes of respiration, the size of the fire-chamber in these stoves must be so regulated as not to heat the cockle or body of the stove (at an average) above the temperature of 300 Fahrenheit. The Derby stove allows the passage of nearly five cubic feet of air per second, which is warmed to about 130° at the instant it escapes from the upper air-chamber into the pipes, leading to different parts of the building. These pipes or flues are provided with dampers to regulate the admission of warm air at pleasure, and are shewn in section at fig. 2, Plate X.

Provided a stove of this construction is well built, and so managed as not to allow the warmed air to attain too great elevation of tempera-

ture, it is not only much more economical than any other method, for warming extensive buildings, but it is equally salubrious with the more recent mode of employing steam pipes for this purpose. The principal disadvantage of the plan appears to be, that it would not be found economical on a small scale on account of the expence of erection; nor could it be easily applied to an extensive building unless constructed in the first instance, or during the erection of the edifice. But as the air passages of this kind of stove are placed several feet below the soil, it affords a convenient mode of admitting a portion of cold air to the interior of the building in the summer season, by means of a revolving mouth-piece, or head placed at the aperture of the air-passage, so as to receive the current of wind at the outer extremity of the passage, and thus convey it to the interior of the building.

The great variety of hot air-stoves which are now manufactured and sold by the different ironmongers, on the original principle of the Derby or Belper stove, it is not necessary to describe, after what has been already said as to the general principle of their construc-

tion. These stoves are at present adapted to every kind of building either on a large or small scale, but they are almost universally constructed of cast iron throughout, which (for the reasons before mentioned) is very objectionable with regard to the salubrity of such apartments. For it has been justly observed by Mr. Tredgold, that atmospheric air should never be heated beyond the temperature of 212° or 250° when required for respiration. Therefore, the hot air which escapes into rooms from the surface of the fire-chamber of these stoves, being in many instances from 300 to 400 degrees, its salubrity will be impaired both by the want of sufficient moisture and by its oxygenous portion beingpartly absorbed by the surface of heated iron.—Part of the evil is avoided by encasing the fire with fire-brick or stone; but the smell of burnt air is always perceptible, more or less, in stoves constructed of cast iron.

With regard to the combustion of smoke, we have already shewn that it is impracticable, by any of the arrangements hitherto adopted. These air-stoves certainly afford the most elegant mode of carrying off the

smoke, whilst their ornamental appearance render them peculiarly adapted for halls, libraries, shops, or other open apartments which admit of free ventilation of the air to carry off the noxious effluvium.

The only variety of stove which demands further notice, is that lately invented by the ingenious Mr. Jacob Perkins.—The object of this gentleman was that of more effectually economising fuel, and, as far as possible, consuming the smoke.

The fire-chamber of Mr. Perkins' new stove nearly represents the lower part of a syphon, opening into an ash-pit beneath. The fuel is supplied from above, and the air admitted on the top of the fuel by a smaller aperture in the short leg of the syphon; by which means the smoke is driven back through the body of the fire, and becomes nearly consumed: after which, the vitiated and hot air passes upwards through the main flue pipe, or laterally, if required for heating buildings on the ground floor, and thence into one of the chimney-flues of the building.

The principal flue pipe is surrounded by

another flue, at an inch or more distant, for the purpose of allowing a current of air to flow between the two pipes; after which the warm air is thrown out into any apartment where heat may be requisite, by means of branch pipes. The interior pipe is furnished with a grating to prevent the escape of shavings, or lighted paper from ascending through the flue.

Perhaps, in point of economy, this arrangement of Mr. Perkins is superior to all other kinds of stoves; for all the heat produced is rendered available, whilst nearly all the nuisance of smoke from ordinary stoves is avoided. But as all the parts of this stove are constructed either of cast or plate iron, it must have a great tendency to vitiate the air for the purposes of respiration; and is, therefore, not so well adapted for warming public or private buildings, where a considerable number of persons reside, or assemble together occasionally, as theatres, chapels, hospitals, &c.

CHAPTER XX.

HEATING BUILDINGS BY STEAM.

This mode of warming apartments has not been in actual use above thirty years; though more used at present in warming manufactories and cotton mills, than any other mode.

Captain William Cook seems first to have suggested the idea, in the Philosophical Transactions for 1745; but as he gives no details of the manner of putting it into practice, it does not appear to have excited any attention for 46 years, or until 1791.

Mr. Watt, indeed, had, in the winter, 1784 and 1785, attempted to heat his usual sitting room by means of a tin plate box filled with steam; but the effect was much less than he had calculated. Mr. Bolton had also made a similar trial in a room in his manufactory

at Soho, and had also heated a bath by steam.

In 1791, however, Mr. Hoyle of Halifax took out a patent for heating green-houses, churches, &c. by an apparatus nearly similar to that described by Captain Cook; though it does not appear that the patentee obtained much benefit from his patent. But the first practical application of steam to heat buildings, is certainly that employed at Mr. Lee's cotton mill at Manchester, about the end of the year 1799; since which time, the use of steam has been rapidly extended.

There are certain advantages peculiar to the use of steam; the principal of which is, the facility by which it can be extended to any number of rooms, although widely separated from each other.

The heat of steam-pipes does not alter the constitution of the air like air-stoves; whilst the air used for ventilation is that of the atmosphere on a level with the building. But in some kinds of air-stoves, the air is frequently obliged to be drawn from below the surface of the earth.

But these advantages of steam heat are

attended with some disadvantages. When a very considerable degree of ventilation is required, the consumption of steam becomes great, and of course more expensive than heated air. The regular supply of steam also requires great attention. Therefore it is not advisable to employ it on a small scale, where it would not allow of a person being kept almost entirely employed in its superintendance. For warming hospitals, prisons, workhouses, or other large public buildings, as well as extensive hot-houses or conservatories, it is not only most salubrious, but also economical. But it will seldom be found advisable to use steam in warming dwelling-houses, unless the establishment of servants is very numerous;—for as the steam is to be supplied by a large mass of boiling water, the boiler in which this is to be heated of course claims attention in the first instance.

The form of the boiler for furnishing steam is usually rectangular, the bottom curved with the concave side next the fire; sometimes the sides are also curved, with the convex surface in like manner turned to the internal part of the boiler; the top is usually a half cylinder,

from whence these boilers are called waggon-shaped boilers. The peculiar advantages of this form are, that the heat of the fire is applied in an equal manner; that the arched form of the bottom supports the pressure of the liquid better than a flat bottom; and, lastly, that the earthy deposit from the water is thrown towards the sides, where the boiler rests on the brickwork, and consequently where the heat being less, there is less likelihood of forming a crust in the boiler.

Some persons give the preference to a cylindrical form; while others, considering that it is difficult to empty a cylindrical boiler on account of the flatness of its bottom, and the great liability to encrust the bottom, use a spherical form for the boiler. In this latter case due precaution must be taken, that no part of the boiler which is exposed to the fire be left uncovered with water, lest it should get injured by the fire.

The form of the boiler appears, however, to be a matter of little consideration, when compared with that of its dimensions.

The experiments of Count Rumford, (essay vi. chapter v.) are in favour of the boiler being

as large as possible. For in order to keep 508 pounds of water boiling, the expenditure of fuel by the hour was something short of one-eighteenth part of the weight of the water; whereas, in a smaller boiler, holding only 284 pounds of water, the expenditure of fuel was more than one-twelfth part of the weight of the water.

Whatever size be adopted, it is always prudent to have two boilers placed close together, that in case of accident, or of any repairs being wanted, the heating of the building may not be suspended.

Mr. Buchanan, who grounds all his calculations respecting steam heat upon the space that is to be warmed, gives as a rule, that for every 2000 cubic feet of space, the boiler should contain one cubic foot at least, when a cotton mill or large edifice is to be warmed by the surplus power of a steam engine; but when boilers are used only for heating rooms by steam, they ought to be considerably larger, since it is by no means proper to work a boiler to the utmost of its powers.

Respecting the material of which the boiler should be made, and also its thickness—the

chief consideration is its cheapness, and the ease with which the water contained in it may be made to feel the influence of the fire.

Copper and Iron are the substances usually employed. But the greater cheapness of the latter metal far overbalances its greater tendency to burn out. Consequently iron boilers are the most usually employed. The experiments of Count Rumford and Professor Leslie have shewn the decisive advantage of using thin boilers. Wrought iron plates rivetted together are now universally preferred to cast iron; as boilers made of cast metal must of necessity be made considerably thicker than those of plate iron.

It is also necessary to make some provision in a boiler adapted for heating buildings by steam, (as well as in the larger class of steam engines) to make it feed or supply itself with water.

There are two methods of effecting this object. In the first method a pipe is laid from a cistern, which ought to be placed so that the surface of the water in the cistern may be about two feet and an half above the surface of the water in the boiler, when filled

to the proper height; for every pound of pressure to the inch above the pressure of the atmosphere; which ought by no means to exceed four pounds to the inch; as a greater pressure will only occasion an increased risk of explosion, expence, and waste of fuel. Indeed, the most usual pressure is that used by Messrs. Boulton and Watt in their steam engines, of two pounds and an half to the inch.

The pipe is to be conducted through an air-tight opening in the top of the boiler, to near the bottom of it, with the end slightly turning up to prevent steam from passing up the pipe. A cock is soldered in that part of the pipe outside the boiler, with two arms extended from it; to one of these arms is fixed an iron rod, which passes through an air-tight stuffing box in the top of the boiler, and has a float annexed to it: the other arm of the cock has a weight suspended to it so as to balance the weight of the float, and the friction of the stuffing box.

Now when the evaporation of the water into steam lowers the surface of that in the boiler, the float on its surface descends, and this acting on the arm of the cock connected

with it, the cock opens and allows water to flow from the cistern into the boiler, until the float rising to the proper height, moves the cock the contrary way, and thus shuts it.

The second mode of feeding differs only from this by the substitution of a valve in the pipe instead of a cock. In both cases it is usual to add another pipe below the cock or valve, and which rises just above the level of the water in the cistern, where its end turns downwards. The use of this pipe is two-fold, for should a vacuum be formed in the boiler by any sudden condensation of the steam, the atmospheric air would enter by this pipe; or if any stoppage takes place in the steam pipes, then the pressure of the steam in the boiler being of course increased, will cause the hot water to be blown out through this pipe into the cistern: so that it acts also as a safety pipe.

At the first filling of the boiler, the cock or valve in the feeding pipe is kept open until the water rises sufficiently high to support the float, and allow it to act.

As the immense strength of confined steam obliges those who employ it to use every pre-

caution against accidents, it is usual not to trust entirely to the self-acting powers of the float, but to have two pipes passing horizontally through the side of the boiler, the one a little below the intended height of the water standing in it, the other a little above it. Both these pipes have a cock fixed to them. At the first filling of the boiler, the lower cock is left open until the water begins to run out at it, which shews the water to have attained nearly the proper height. And it will be proper, during the working of the boiler, to open these cocks frequently, to be certain that the float and feeding apparatus is in proper order; for in this case the lower gauge cock should give out water, and the upper cock should give out steam.

Instead of these gauge pipes being placed quite close together, the lower pipe sometimes opens into the boiler at a lower level, some inches below the intended height of the water, and instead of a cock to be opened being fixed in each, their outward ends are connected by a glass tube, such as is used to make barometers: and as the water will stand at the same height in this tube as in

the boiler, the height will be immediately visible.

This method of exhibiting the height of the water in the boiler, may be turned occasionally to advantage, by enabling the proprietor to form a judgment of the relative value of different substances used for fuel. For if the self-action of the feeding apparatus is stopped for an hour, and the depth of water evaporated during that time be measured by observing the difference of the heights, as shewn in this glass tube; this evaporation, compared with the consumption of fuel, will afford the relative value of the fuel.

In respect to the depth of water that ought to be kept constantly in the boiler, it depends much on the use to which the steam heat is to be applied. When the heat is only wanted in the day-time, and that perhaps but for a few hours, no more water need be kept in the boiler than is sufficient to prevent a want of water, in case of the fire being accidentally neglected. For if the boiler be filled to a great depth, much fuel would be wasted in heating the water to the boiling point, and consequently it would be a long time before

the steam would be sufficiently strong to fill the pipes.

But when steam is applied to heat hot-houses or conservatories; in which it is necessary that the heat should be continued by night as well as by day, and constant attendance cannot be given during the whole of the night; then a good depth of water should be kept in the boiler, that the great mass may retain the heat, and keep the steam pipes full in case of any neglect.

As too much precaution cannot be used against accidents by explosion; the use of steam gauges and safety valves ought never to be neglected.

The steam gauge is simply a bent iron pipe communicating with the boiler, and open at the upper end. A small quantity of quicksilver is poured into the bend of the pipe, and this by the power of the steam is forced up the open leg of this inverted syphon. A float with a deal rod marked with inches and parts, which rests on the surface of the quicksilver shews by its rise the power of the steam.

On account of the great specific gravity of mercury, = 13.6 to 1 (water), each inch of

elevation corresponds with a pressure of $\frac{472}{1000}$ths of a pound to the inch; or 2 inches $\frac{117}{1000}$ths of the gauge equals the pressure of a pound to the inch of the valve. Hence the inspection of this gauge shews at all times the strength of the steam, and if no more quicksilver is poured into the bend than would suffice to exhibit by its rise the intended pressure at which the steam is to be worked, then the blowing out of the quicksilver will shew that the intended pressure is exceeded and the pipe will come in aid of the other apparatus, by which the safety of the boiler is secured.

The valves (to which the specific appellation of safety valves are applied) are of two sorts, namely, those intended to prevent the explosion of the boiler or pipes through any accidental stoppage of the free passage of the steam, and those intended to prevent the collapsing of the sides of the boiler or pipes, in case of sudden condensation of the steam.

The safety valve against explosion is merely a cylindrical cast iron box, containing a valve resting on a seat which is generally made conical. The valve is loaded in proportion to

the size of the hole and the pressure at which the steam is to be worked.

The safety valve against collapse is merely a circular hole made in any convenient part of the top of the boiler, which is stopped inwardly by a valve, balanced against the hole, by a weight at the end of a lever. Hence if any sudden condensation of steam takes place, the pressure of the atmosphere on the hole forces down the valve, and admits the entrance of the air to supply the place of the steam. In large boilers it is necessary to have a hole of sufficient size to admit the occasional entrance of a workman into their interior. This man-hole as it is termed is closed by a plate of metal, screwed down to the boiler; the hole being only opened when it is necessary to examine or clean the boiler.

Mr. Tredgold, who has bestowed much attention on the tenacity of metals, has, with the usual partiality that most men betray for a favourite object, proposed not only to use this tenacity as a steam gauge; but also on the same principle to convert the man-hole of a boiler into a safety valve.

This object he would effect by causing the

cover to be pressed down upon the man-hole by a cast iron bar, wedged in two standard loops on the opening, and acting on a fulcrum placed in the center of the cover. The size of the bar to be so adjusted as to break whenever the pressure of the steam exceeded the intended force. His rule for this adjustment in the case of the man-hole being circular is, that the cube root of the intended pressure of steam calculated by pounds on the inch, being multiplied by the 34th part of the inches of the diameter, will give the side of a square bar in inches.

When the number of contrivances to prevent explosion already enumerated are considered, namely, the additional pipe to the feeding apparatus, the steam gauge, and the proper safety valve, it does not seem necessary to have recourse to this mode of fitting up the man-hole, more especially in boilers which are used only to furnish steam for warming rooms, as the passage to the pipes ought never to be entirely stopped.

There is, however, a different sort of safety apparatus that remains to be noticed, to guard against danger of another kind, that of burn-

ing the bottom of the boiler from a want of water, in consequence of some defective action of the feeding apparatus.

For this purpose a pipe is affixed to the boiler of about two inches and an half in diameter, open at both ends, and of sufficient length to reach from below the proper level of the water in the boiler to a height above it equal to rather more than equivalent to the intended pressure at which the steam is to be distributed, according to the proportion of 2 feet $\frac{4}{10}$ths in height for each pound of pressure to the inch. The upper end of the pipe is made like that of an organ pipe, or else it opens into a hollow globe. Should any accident prevent the due action of the feeding apparatus, and the water by evaporation be wasted below its proper level; as soon as it fall down below the lower orifice of this alarm pipe, the steam would rush through the pipe and from the conformation of its upper extremity make a noise that would alarm the neighbourhood, and the want of water could not escape notice, and full time would be allowed to remedy it before there would be any danger of the bottom of the boiler being injured.

CHAPTER XXI.

SUSPENSION OF STEAM BOILERS, &c.

The suspension of the boiler, and construction of the fire-room, is the next consideration; and on this point various plans have been followed by different engineers.

In fixing the ordinary boilers the grate is placed about fifteen inches below the bottom, in order to allow sufficient space for the depth of fuel. The area must be proportioned to the quantity of fuel intended to be burnt in every hour. For Newcastle coal to burn a bushel by the hour, the grate it is calculated should have 8 square feet of surface; and so in proportion for the consumption of more or less fuel.

The grate is best formed of loose bars resting on cross bearing bars of sufficient strength, in order that they may be easily taken out,

and renewed when necessary. The bars should be from one inch to an inch and a half thick, and from 2 to 3 inches deep, according to the size of the grate; and made rather narrower at bottom than at top.

It is advisable to have two small fire-chambers in preference to one large one for heating boilers of any magnitude. It not only disperses the heat more uniformly over the bottom of the boiler, but it prevents the coal from being vitrified by the intense heat which is often produced in large furnaces, where there is a powerful draught. The vitrification of the coke is productive both of waste of fuel and additional trouble, with a certain loss of heat in raking out these clinkers as they become attached to the fire-bars. Too high a degree of heat is also very destructive to the bars; which ought never to be higher than a full red or low red heat. At a white heat the iron and coal manifests a strong tendency to unite, and form the slag, clinker, or carburet of iron.

Many different statements have been made of the quantity of coal necessary to feed the fire. Mr. Buchanan, in his Treatise on the Economy of Fuel, adopts the rule of Messrs.

Boulton and Watt, and considers 14 pounds of Newcastle coal by the hour necessary for every 25 cubic feet of the content of the boiler; with the reservation that in general a large allowance ought to be made for defects in the furnace, and the inattention of servants.

Mr. Tredgold, in his Principles, envelopes his rules in abstruse combinations, although after all, they afford only rough estimates. As the different qualities of coal, slight variations in hanging the boiler, or in the height and area of the chimney, and different degrees of care and attention on the part of the stokers, will produce very great variations in the quantity of fuel consumed.

With regard to the quantity of surface of cast iron pipe necessary to heat a given area, Mr. Tredgold gives us the following estimate:—if the constant number 3160 be divided by the difference between the temperature, T, of the surface of the steam pipe, and the intended temperature, t, of the room; the quotient will give the surface, s, of steam pipe that will be required; allowing the quantity of fuel per hour that would bring a cubic foot of water at the mean temperature, to the boiling point. Now this effect is producible by 1

pound $\frac{2}{10}$ths of Newcastle coal; consequently each bushel, or 84 pounds of coal will supply heat to 70 times this surface; on the supposition that the condensed water is returned into the boiler. But if the disposition of the steam pipes is such, that the water is not returned into the boiler, then about one twelfth part of the heat will be lost.

Notwithstanding the apparent accuracy of these calculations, there still remains an indefinite allowance of fuel to be made for loss of heat at the boiler, which, in small boilers, is very considerable.

It is most usual to make the heated air and smoke pass round the bottom of the boiler in a small channel for that purpose, and in some cases this channel passes through the boiler, and from thence into the chimney: but this construction is by no means so advantageous as it is usually supposed; for the velocity acquired by narrowing the passages, only tends to prevent the heated air and vapours from parting freely with their heat.

It is always advisable to place a damper at the chimney-vent, to move either horizontally or vertically. This damper should, in all cases, have marks, that the stoker may be

enabled to judge of the opening into the flue of the chimney.

To explain this important subject still further, some examples, extracted from the works and patents of those who have studied the subject with the greatest attention, are here added, and illustrated with the following engravings.

The XIVth Plate exhibits the manner adopted by Count Rumford, for setting boilers. The particular purpose for which this boiler was intended, was the process of brewing; but the principle being simply that of boiling a large quantity of water in a short time, the mode of setting is equally applicable to boilers intended to produce steam for heating buildings.

The ash-room is small, as shewn at *a*, fig. 1, and *a*, 5; it is capable of being closed with an iron door, furnished with a circular register, *(see fig. 6)*, to regulate the admission of air to the fire. The upper part of the ash-room has a contraction just under the grate, which Count Rumford conceived had a considerable effect in augmenting the heat of the fire. The fire-bed is formed of a concave porcelain basin pierced with holes, in order to sustain the heat more effectually than iron

bars. The fire-room is large, and the back, as may be seen in fig. 1, slopes gradually from the grate to near the back of the boiler; but the sides are carried up almost vertical, as shewn in fig. 5, to allow room for the side flues under the bottom of the boiler. The feeding-hole is a little above the grate, and has a short dead plate, slightly sloping towards the back. It is closed by two doors, one within the other, as shewn in fig. 1. The brickwork on each side of the ash and fire-rooms, fig. 5, *b*, *b*, is worked hollow; as is also the back of the furnace, behind the ash and fire-rooms, as shewn in fig. 1, *b*. These hollow spaces are economical, and they add to the durability of the furnace by preventing its unequal expansion.

The flues proceeding from the fire-chamber are represented in the horizontal section fig. 3; being divided to the right and left by the middle partition *b*, at the back, and having reached the front of the boiler again, carry off the smoke and hot air at the back by the flues *c*, *c*. Fig. 4 is another modification of the flues at the back of the boiler, in order to retard the escape of the smoke and hot air

till it should give out all its available heat; but Count Rumford found the more simple arrangement of fig. 3 the most advantageous in practice. Fig. 2 is a half section of fig. 4, shewn vertically.

The boiler erected at Munich by Count Rumford was 11 feet 6 inches long, 9 feet 7 inches $\frac{3}{4}$ wide, and 2 feet deep. The middle flue over the fire was 44 inches wide, one side flue 20, and the other 19 inches wide; all were 14 inches $\frac{1}{2}$ deep; the narrow channels to carry the heated air to the chimney were 7 inches wide, and 16 deep; the circuit of the flame and air under the bottom of the boiler, was, of course, about 30 feet, before it passed into the chimney.

In the original construction, with the side flue round the edge of the bottom, 1204 wine gallons of water (being the first morning boil) was heated in four hours four minutes, with the consumption of 575 Bavarian pounds of dried pine-wood. The boiler being then emptied, and filled again with water, the second boiling required two hours and twenty-six minutes, and consumed 550 pounds of wood; the third boiling was of 1685 wine

gallons of water; it took three hours seven minutes, and consumed 650 pounds of wood.

In the altered manner, without the circulation of the heated air, &c. round the edge of the boiler, 1685 wine gallons of water were boiled in two hours fifty-nine minutes.

The figures in Plate XV. exhibit another mode of setting boilers. The ash-room expands from the bottom upwards towards the fire-bars; after which the fire-room contracts, as shewn in the side and front sections *a*, *b*, figures 1 and 2. It is supposed that this figure concentrates the heat more effectually towards the middle flue, *a*, fig. 3, under the bottom of the boiler, and thus increases its intensity. But it will obviously tend to destroy that part of the bottom faster than the divisions resting on the side flues. The most economical arrangement is doubtless that which disperses the heat most uniformly over the whole surface of the boiler. In this arrangement the ash and fire-room project forward a little from the front of the boiler, in order to allow the coal to be introduced by means of a hopper, *c*, fig. 1, or *b*, fig. 3.

This hopper is formed of cast-iron; its bot-

tom turns on hinges in the front, and may be moved by means of a lever attached to it: the top is also furnished with a lid moving on hinges in the back. When coal is to be added, the lid is turned up, and the fuel put in, the bottom being kept in its place, either by a counter weight at the end of the lever, or by some other contrivance. The lid is then shut down to prevent the entrance of air with the coal, and the bottom is opened, that the coal may fall on the dead plate before the fire. By this means the gases yielded by the raw coal are burned and converted into flame in their passage through the already ignited coal, and with a view of securing this, the lid of the hopper may be kept raised a little, as experience may point out, to supply a small current of air to maintain this combustion. The stoking-door *d*, fig. 1, is opened before each fresh charge of coal, to push the coal on the dead plate upon the grate, and thus make room for the new charge.

The disposition of the flues under the bottom of the boiler, as exhibited in fig. 3, are exactly similar to those already described. These flues terminate in the back of the fur-

nace, at *c*, fig. 3, from whence the heated air and smoke is carried to the chimney.

The unequal expansion of the masonry is guarded against, partly by the empty spaces, *a* and *b*, fig. 4, left on the sides of the fire-room, and partly by the hollow arch, *f*, fig. 1, left behind the fire-room. A space is also left between the lower part of the boiler, and the wall to keep in the heat.

The fifth and sixth figures of the same plate are to shew the form of a boiler devised by Mr. Curaudau, for the purpose of concentrating the force of the fire to a single spot in the center of the bottom of the boiler, and forming this bottom concave, to the end that the retardation given to the current of heated air, by obliging it to descend, may cause it to give out more of its heat to the boiler than if it were rapidly circulated horizontally under the bottom.

The ash-room and grating are on the common construction ; the latter is placed under the center of the boiler, and therefore a recess is made in the wall that the stoker may get to the fire. The sides of the fire-room are made to converge as they ascend, so that

the flame and air passes through a narrow throat into the space left under the lower part of the boiler; from whence it is carried off by the chimney.

This form of the bottom of the boiler has a considerable advantage in respect to the saving of fuel; but its construction is attended with some difficulty, and the whole force of the fire being directed to a single point, this part is apt to get burned, and want repairs.

CHAPTER XXII.

CONSTRUCTION OF FURNACES.

FIGURES 1 and 2, Plate XVI. represents another mode of constructing furnaces, so as to make the fuel give out the greater part of its heat to the bottom and body of the boiler. A fire brick or tile, *a*, extends across the bottom of the boiler about midway of the depth of the fire-room, and the back of the fire-bars have also a projecting edge, *b*, in order to deflect the current of the flame to the bottom of the boiler; after which it passes on to the back of the boiler, and enters two iron flues which pass through the boiler, as shewn at *a*, *a*, fig. 2; from whence it again returns through the side flues *b*, *b*, into the chimney-flue *c*, shewn in fig. 1.

This plan of extending the length of the flues as much as possible, in immediate contact with both the exterior and interior of the boiler has been adopted by Mr. James Neville in his recent patent for an improved steam engine and furnace. The steam engine (though the most economical and simple in its operation which we have hitherto seen) is not within the province of our subject to describe. The mode of economising fuel and consuming the smoke is however at once simple and effective.

The fire-room, which extends the whole breadth of the bottom of the boiler, is divided in the middle by a partition of fire-brick from front to back, with the exception of a small passage or communication near the back, which may be closed at pleasure by a damper. The double fire-chamber has two separate doors for the reception of fuel in the usual way; and a common draught or ash-hole beneath; with additional draught-holes in front, if necessary, in order to increase the current of air.

Supposing the fire to be lighted in each compartment of the fire-room, and fresh coals

are thrown on the right-hand fire; the passage on that side into the main chimney-flues being closed by a damper, the smoke is obliged to pass over the whole surface of the live coal in the left chamber, by which means, nearly, if not the whole of the visible part of the smoke is consumed. On charging the left hand fire-place with fuel, the reverse opening and closing of the dampers is, of course, required.

The consumption of the smoke in this manner not only obviates the nuisance to the neighbourhood from the disengagement of dense smoke, but it enables the flues to be extended to a greater length in contact with the boiler, in consequence of their being less liable to be choaked up with soot.

Another arrangement, and perhaps the best (in all respects) which has been devised for consuming the smoke in steam boiler furnaces, is that of Mr. Geo. Chapman of Whitby; an account of which is given in the last volume of the Transactions of the Society of Arts, &c. from whence the following account is an abstract in Mr. Chapman's own words.

"To heat the air before its admission into

the furnace. This I do by casting the grate-bars hollow from end to end, so that they form a series of parallel tubes, which open into two boxes, one placed in front, and the other behind the grate. In the front box, directly underneath the fire-door, I make a register to open and shut, to any extent, at pleasure. The other end I connect with the brick work directly under the fire-bridge, which fire-bridge I make *double*, with a small interval between, say one inch; the interval to go across the furnace from side to side, and rather to incline forward, or towards the fire-door, so as to meet and reverberate the smoke on to the ignited fuel in the grate, which causes it to inflame and become a sheet of bright fire under the bottom of the boiler.

" From what I have said it will appear, that if the front register is open, or partially so, there will be a great draught of air through it, along the interior of the grate-bars, thence into the flue of the fire-bridge, and out of the orifice at top, which air will be heated in its passage through the bars, before it comes in contact with the smoke, when it will give out its oxygen, and cause it to inflame.

"Such was my view of this part of the subject in theory, and I have found it to succeed in practice, in a small engine of my own. But a further improvement was necessary to make it quite perfect. There are few people who are aware of the extent of the mischief arising from the old method of charging a grate by the front door. Now, in my engine, (which is only two-horse power), I calculated that every time the fire-door was opened to stir the fire and replenish the fuel, there could not be less than from forty-five to fifty cubic feet of cold atmospherical air admitted into the furnace, which so cooled the heated gases, &c. that, however complete the plan was in other respects, the smoke could not possibly inflame, from being so cooled, till a considerable time after the fire-door was shut.

"To obviate this I have adopted a cast-iron hopper above the fire-door, with a type at the bottom that has two pivots at one side and opens at the other; one pivot goes through the end of the hopper, and has a counter lever to keep the type shut when a sufficient quantity of coal for a charge is on it. The top of the hopper is covered with a lid which I shut

down during the time of firing, then, by lifting the lever which opens the type inside, the coals slide down on to the fore end of the grate bars, which is only the work of a moment. It is evident that no quantity of cold air can thus get into the furnace; in fact, it is not possible for any person that does not see the operation of firing, to know when fresh fuel is added by looking at the top of the chimney. The smoke that issues is never more than a light grey, just perceptible, but in a general way, is not seen at all.

"The coals last admitted, after lying a short time at the front of the more ignited fuel, become partially coked, and just before I admit a fresh supply, I push the last charge further along the grate, by a tool made for the purpose, which remains constantly in the furnace. It consists of a plate of iron about four inches broad; its length goes across the grate with a round bar of iron rivetted into its centre, at right angles, to form a handle, which comes through a hole made in the bottom of the fire-door, and is long enough for a man to use with both hands, so that he can either push from, or pull towards him, to

manage the fire within, without opening the fire-door, except when the grate wants cleaning, &c. &c. For better knowing when the fire wants stirring, or replenishing, I have a hole, about an inch in diameter, in the fire-door, to look through, covered by a piece of iron which hangs by a rivet above.

"After I have used the above instrument, I pull it up close to the fire-door, where it remains till it is again wanted; and the coals, when let into the fire, fall down beyond it.

"The above-written account constitutes the whole of my improvements as far as is required by the Society, but not the whole of the advantages gained by my invention. For instance, the durability of the grate-bars by the admission of air through them. I may add, that I examined my own yesterday, and I do not find them any worse, although they have been in use four months. In conclusion, I beg leave to refer you to the accompanying certificates by gentlemen who have had an opportunity of personally viewing my improvement, and who, I flatter myself, are all people of the first respectability."

The latter part of Mr. Chapman's inven-

tion, respecting the hopper and mode of supplying fuel, the reader will perceive is only a slight modification of the methods previously in use; and shewn in Plate XV. But the mode of supplying a current of hot air by means of the hollow bars and boxes is very ingenious, and no doubt, more effective in de-carbonising or consuming the smoke, than any other plan which has been hitherto proposed.

Mr. Chapman truly remarks, that it is the reduction of temperature which principally occasions the evolution of a dense smoke, on charging a boiler fire with fresh coals, in the ordinary way. Could the charge of coals be heated in a confined chamber or hopper to a temperature of about 600°, previous to their being thrown on the fire, perhaps the escape of smoke would be nearly if not quite invisible from the chimney-flues, whilst another advantage results in point of economy, from the arrangement of Mr. Chapman—that of preventing the reduction of temperature beneath the boiler; and consequently keeping up the constant production of steam.

Plate XVI. fig. 3, delineates the section of

a furnace which varies in some degree from the before mentioned. The coal is introduced by a hopper over the front of the fire, through a grating which prevents the passage of large coal. The air is admitted to the fire, not through an ash-room and grate, but through curved bars in the front of the fire, the same as in an ordinary stove grate. The burning coal is pushed backward by the stoker along a brick hearth under the bottom of the boiler, until its combustible matter being exhausted, the coal reduced to cinders falls into a pit in the back of the furnace, from whence they are taken out by a side door, not seen in the section.

The air that has passed through the burning coal is conducted by a flue in the back of the furnace into another which passes lengthwise from the back to the front of the boiler, *a*, *a*, as in the figures 1 and 2.

Fig. 4, Plate XVI, is another variety in the common mode of setting boilers. The grate is level, and brought forward to the front of the boiler. A bridge at *a*, fig. 4, admits the passage of the flame, smoke and heated air into the flue, while another bridge, *b*, forces

the flame, &c. to turn downwards, for a few inches and then to rise up and pass along the bottom of the boiler, to the back, where the flue ascends and is continued horizontally round the boiler to the back again, and from thence into the flue of the chimney.

At the commencement of the smoke-flue, that is to say where the two bridges obliges the smoke, &c. to turn down, openings are made in the back wall of the ash-room, and fire-room to admit a supply of air to the heated vapours, and finish the combustion of whatever matters might be carried off unburnt, for want of a sufficient supply of air.

The outer flue, *c*, is only necessary when a boiler is made to evaporate brine, sugar, or other liquids for preparing them for crystallization. In this case a wide steam-pipe from the back of the boiler is placed between the boiler and a flue of this kind, and an opening being left in the front part of the boiler, then the fire being lighted, and the brine or other liquid brought to boil, a current of air will pass along the surface of the liquid in the boiler, and pass down this flue and along the bottom of the furnace to the ash-pit, and carry the steam along with it.

This current of air not only promotes the evaporation, but it also carries off the steam and passes it through the fire and up the chimney into the open atmosphere.

An ingenious method of condensing the greater part of the smoke or noxious vapour from furnaces has been recently proposed by Mr. Jeffery of Bristol; and, in the process of smelting ores, or in metallic furnaces, it is likely to prove a valuable improvement.

The flue which proceeds immediately from the fire-chamber ascends to a certain height in a vertical direction, and then passes horizontally a short distance, when it is made to descend nearly parallel with the ascending branch, and having its extremity opening near the surface of the ground.

Over the top of the descending flue a cistern of water is fixed, the bottom of which is perforated with holes, by which means a shower of water may be kept running at pleasure, while the furnace is in operation. This shower of water not only condenses the greater part of the smoke and noxious vapours, which are carried off in the form of black water, at the lower end of the flue; but

the passage of the water also serves to increase the draught of the chimney in a very considerable degree.

Mr. Watt, in 1785, took out a patent for the construction of furnaces which are somewhat different from any of those delineated in the preceding plates, the principal draught through the fire being from above.

The front and side section of Mr. Watt's furnace is shewn in figures 1 and 2, Plate XVII. The ash-hole, *a*, is only for the purpose of drawing out the ashes, it is made much smaller than usual, and is kept closely stopped, to prevent any false draught of air through it.

Instead of a grate, an arch of fire-brick is thrown across the furnace at *b*, just over the ash-hole door, to support the coal: this arch goes only so far into the ash-room as a little beyond the back wall of the hopper, from the back of which another arch, *d*, is thrown across the back of the fire-room, and a large portion of the ash-room.

On a level with the top of the arch thrown across the ash-room door, there are two narrow slits, *b*, *b*, fig. 4, left in the front wall.

The use of these openings is to admit a slight current of air horizontally into the mass of burning fuel, for the purpose of consuming the smoke.

The mouth of the hopper-shaped fire-room which contains the coal is shewn at *c*, fig. 1, a transverse section of it in fig. 2, and a horizontal section in fig. 3. Even with the mouth of the hopper, another small opening is made in the front of the furnace, the front view of which appears at *c*, in fig. 2. This opening is for the same purpose of admitting a further current of fresh air, to strike against the flame as it passes over the bridge, and proceeds under the bottom of the boiler from a flue, which carries it round the lower part of the boiler, and from thence into the chimney.

The same inventor describes, in his patent, another furnace, delineated in the fifth figure of the same plate. This furnace has two fire-places, one behind the other, the backs of which open one into the other. Both the furnaces are of the common construction, and differ only in their size. The front and largest sized fire-place, *a*. fig. 5, has its grate nearly under the center of the boiler.

The small fire-place behind, *b*, is to make a fire of cinders or coke, for the purpose of burning the smoke of the larger fire of the front grate, as it passes over this clear fire, which being but thinly spread with fuel allows the passage of more air than is necessary for its combustion.

As the smoke heated air and steam formed from the combustion of the hydrogen in the fuel, ought not to be suffered to escape from the boiler at a less temperature than that of boiling water, the heat thus carried off is sometimes applied to use, before they are suffered to enter the flue of the chimney.

For this purpose some have made the communication between the furnace of the boiler and the chimney, by an iron pipe carried through a cistern of water; by this means the water was not only warmed but the quantity of smoke reduced; and the warm water used to feed the boiler.

The principal desideratum in hanging boilers where steady heat of no great intensity is wanted, is to give a proper proportion to the area of the flue and height of the chimney. The usual practice has been to build the chim-

ney as high as circumstances would allow; yet unless this is accompanied with a certain area of the flue, the height may be prejudicial.

Dr. Macquer first observed this in his experiments upon the fusion of certain stones, as related in the Memoires de l' Academie Royale des Sciences for 1767. Since which period a great variety of experiments have been made by practical men for the purpose of arriving at some certain data in building furnaces. It appears, however, that every rule of this nature must have reference to the immediate object of the manufacture, or the heat required. Thus, although the air-furnaces of founderies or glass-houses require chimneys of great altitude; yet in cases where a moderate degree of heat is employed, the chimney should not be too high.

The Scottish distillers availed themselves of the most scientific principles in constructing their furnaces a few years since, so as to make the whole of the heat given out by the fuel applicable to the process of distillation, and consequently to work off their stills

with greater rapidity. And to such perfection had they arrived, as to work off an 80 gallon still, and re-charge it with wash, in the short space of three minutes.

The fire-places of these stills were 15 inches deep, the fuel large flaming coal; the grates 4 feet 3 inches from front to back, and 3 feet 6 inches, or 4 feet wide. The flue of the chimney was always four feet square. The chimney was built 60 feet high, composed of two walls, placed at three inches distance, but tied together, at certain distances, by long fire-bricks: the inner wall was 9 inches, the outer wall 18 inches thick at bottom, narrowing gradually to 9 inches at top. When the chimneys were built only 36 or 40 feet high, the draught was not sufficient, and when more than 60 feet, it was too strong, and the bottom of the still was injured. When the chimneys were built solid, they were apt to give way from their unequal expansion.

From these proportions for distillery-furnaces, it will be easy for any intelligent workman to calculate any other proportion for obtaining a given heat for other operations.

If the chimney be too high, more air will pass through the fire than is necessary, in order to consume the fuel; while a chimney too short will not have sufficient draught for a large fire-room.

CHAPTER XXIII.

OF STEAM APPARATUS.

In order to apply steam thus produced, for heating buildings, it must be conducted to the various parts of the building, by pipes properly disposed.

These pipes are usually made of cast iron, about three inches in diameter, and as thin as they can be formed, which is rather less than three-eighths of an inch.

In some cases, as in laundries, copper pipes are preferable, as iron pipes would injure the linen.

Pipes of tinned iron plate are also occasionally used. But although cheap in the first instance, they are far less durable, and (unless painted black) give out very little heat in proportion to their surface.

Lead pipes are totally unfit for conveying steam, as its heat expands them so much, that they lose the power of retraction; and by frequent repetition of heat, they at length open in cracks.

The quantity of surface of pipe necessary to heat rooms, depends altogether on the nature of the building, the degree of ventilation required, and the temperature at which the rooms are to be kept.

In cotton mills, according to Mr. Buchanan, the space heated by each square foot of surface, varies from 170 cubic feet to 200; while a small chapel was made comfortably warm by only a square foot of pipe to each 400 cubic feet of area.

In these calculations the steam was of the strength usually employed by Messrs. Boulton and Watt; that is to say, with the safety valve on the boiler loaded about two pounds and an half to the square inch.

Mr. Tredgold's mode of calculating the quantity of steam pipe necessary, has been already given.

The direction in which the pipes are placed is also of considerable importance, and ought

to be perfectly independent of the building they are intended to heat. Some persons have endeavoured to make the vertical pipes serve as supports to the floors; but this is by no means advisable, as their alternate expansion and contraction by heat soon destroys the connection of the floors with the walls, and renders the building insecure.

In general a pipe reaches vertically from the boiler to the top of the building, having horizontal branches for each floor, with cocks to each, so that as many of the floors as are desired may be heated, without expending steam where it is not wanted. The air contained in the pipes, before the steam is let in, is allowed to escape by openings with cocks at the ends of the horizontal branches; and the steam condensed in them is conveyed by small pipes connected with their respective ends back to the boiler.

Sometimes, (as in Mr. Houldsworth's cotton mill) the main pipe proceeds vertically to the upper floor of the building, then horizontally along that floor to the further end, whence it descends to the next floor, along which it proceeds horizontally, and thus successively,

until it reaches the lower floor and boiler again. In this mode, all the floors must be similarly heated; but should any accident happen to the pipes, the heating of the whole must be stopped, until the repairs are finished. —In heating churches, the pipes are usually carried round the walls, under the seats.

Whatever method is used, a cock should be inserted at the joining of the main pipe with the boiler; and in general the ends of the pipes should have small openings or cocks not shutting close, to allow some steam to escape, as well to prevent the return of air into the pipes, as to shew that the steam fills the whole length of the pipes.

When it requires several pipes to produce the necessary quantity of surface, they should each be furnished with cocks, that they may be filled separately with steam; and thus the quantity of heating surface may be augmented or diminished at pleasure.

Many methods have been used to join the several lengths of steam pipes, according to the situation in which the pipes are placed, which are shewn in the XVIIIth Plate. It is in all cases necessary that the joints should

be held together with some force, otherwise the alternate expansion and contraction will soon render them incapable of confining steam.

The most simple joint for horizontal pipes is that called the spigot and fosset joint, shewn in the four first figures of Plate XVIII. In this mode of joining, the spigot or end of one pipe is merely received into the larger end of the other pipe, and the space (which ought to be as small as possible) is filled up with iron cement—Which is formed by a composition of 40 pounds of iron borings, beat up with one pound of sal-ammoniac and half a pound of sulphur.

If much inequality of expansion is expected, the joint may be stuffed with hemp, wool, or cotton, mixed with stiff white lead paint, ground with a little red lead to harden it. Pipes joined in this manner sometimes break in the fosset, from the greater expansion of the spigot.

Pipes cast of an uniform diameter throughout their whole length, are connected by the common thimble joint, as exhibited in fig. 5, 6, and 7. The thimble, which is a short

cylinder of cast iron, being previously drawn over one of the pipes, their ends are brought together, and the thimble drawn over the joint, which is secured as before.

Sometimes the thimble is composed of two half cylinders, and secured by a hoop or two of wrought iron round it, the ends of which are rivetted together, as shewn at fig. 8. This is principally used when the fosset of a joint has cracked, and it is necessary to repair the joint. But more usually the two pieces of the thimble are made as in fig. 9 and 10, with holes to receive screws with nuts, by which they may be fastened together.

The ends of plain pipes might be placed home against the edge of a ring, turned up externally on each side, to receive the pipe, and leave only a small vacancy for cement, as in fig. 11 and 12; but this joint is manifestly inferior to any other method.

The ends of the pipes are sometimes cast as shewn in fig. 13, so that when the ends are brought together, the joint is made good by a wrought iron hoop, which is screwed or rivetted together. (*See fig.* 14 *and* 15.)

But the strongest and best joint is that in

which the pipes are cast with flanches at their ends, having holes in them for screws, which, by their nuts, bring the flanches together: a piece of flannel or mill-board dipped in white lead paint being previously placed between the flanches. The figures 18, 19, and 20, represent these flanche joints, which should always be preferred for horizontal pipes.

The joints of vertical pipes are kept tight by the weight of the pipe, and they have usually only a small shoulder at the upper end in which the lower end of the upper pipe rests, as in fig. 16. Sometimes the shoulder is made, as in fig. 17, on the inside of the lower pipe.

The small wrought iron pipes used for communication, are joined by what is called the union joint; which is a kind of thimble which screws over the joint, as is represented in fig. 21, 22, and 23.

For bends or angles in the direction of the pipes, the pipes are cast accordingly, as shewn in fig. 24 and 28: the joints there represented are common spigot and fosset joints; but any others might be used.

When a branch is wanted to be given off

from any pipe, a hole of sufficient size may be cut, the branch pipe added, and the joint secured by what is called the saddle joint, shewn in fig. 25, 26, and 27. The end of the branch is made to fit half round the main pipe, the piece called the saddle fits the other half, and the whole is connected together by two wrought iron hoops, as in the hoop joint.

When steam is to be conveyed to a distance, the greatest care is required to prevent its heat from being lost during its passage. For this purpose the steam pipes must be inclosed in other pipes, or in wooden cases, which may be filled either with chaff, ashes, or any similar matter. These pipes should allow about three inches thickness of the lining all round the steam pipe; and if conveyed under ground, as is becoming common in gardens, they should be farther enclosed in drains, in order to keep them dry.

A cheap mode of confining the heat as the pipes pass through places not wanted to be heated, is to wrap straw ropes round them to a considerable thickness, and covering it with a coating of mortar.

It is in all cases advisable to return the

water condensed in the steam pipes to the boiler, by a small pipe, proceeding from the ends of the horizontal branches to the cistern of the boiler, the branches having a gentle slope given them, to facilitate the passage of the water; although, in general, the steam will drive the water before it, unless the diameter of the pipe is very great.

Various methods are used to close the ends of the steam pipes, yet permit the passage of the air, and the water of condensation.

The original and most usual termination of the branch steam pipes is shewn in Plate XIX. fig. 8, where *a* is the end of the steam pipe, *b*, a small pipe with a cock, which is opened when the fire is lighted, and allows the escape of the air. When steam appears, the cock is turned, and a small quantity only of steam is allowed to escape by the pipe, *c*, which communicates with a pin-hole in the air-pipe, between the cock and the steam pipe: *d* is a syphon pipe, screwed on the under surface of the steam pipe: this syphon receives the water of condensation, and conveys it to the cistern of the boiler. The bend in this syphon pipe must be at least ten feet

deep, to prevent the water, which serves as a valve, from being thrown out by the sudden oscillations to which it is subject: and the syphon itself must be carefully guarded against the action of frost. The diameter of the pipe of this syphon must be sufficiently large to carry off the water of condensation as fast as it is formed, while a larger diameter would only expend heat in vain. Wherever a sufficient depth can be obtained for placing this syphon, it is always to be preferred for the purpose of returning the water.

Another kind of syphon for carrying off the air and water of condensation is shewn in fig. 5; *a*, is a close iron box connected with the under surface of the ends of the branch steam pipes, *c*, is a syphon pipe which connects this close box, *a*, with a similar cast iron box, *b*, (which is open at top,) and has a pipe, *d*, that leads to the cistern of the boiler. The syphon being filled with water, the air driven on by the steam drives the water before it, and escapes at the open top of the box, *b*. The water condensed by the steam pipe passes gradually off by the pipe, *d*, the syphon remaining full.

Where a sufficient depth cannot be obtained for the construction of these syphons; the air is allowed to pass out and enter it again when necessary, either by means of a cock to be opened and shut by the engineer on duty, or by two safety valves placed near the end of each branch of the steam pipe; one valve opening outwards, the other inwards; and the water of condensation is carried off to the cistern of the boiler by an apparatus represented in Plate XIX, fig. 6. A hole being made in the under surface of the steam pipe, an iron box, *a*, containing a puppet valve, whose opening is regulated by a lever having a hollow ball of copper at its end. As the water condenses in the steam pipe it runs into this box, and when a certain quantity of it has collected, the action of the hollow ball which floats on its surface raises the puppet valve, and allows the water to run off by the pipe, to the cistern of the boiler.

Sometimes a simple float without a lever is used to open the valve.

Hitherto no notice has been taken of the expansion of the pipes; but this must be carefully recollected, and provided for. Mr.

Buchanan thinks the allowance of one-tenth of an inch for each 10 feet in length of cast iron steam pipe is sufficient, but Mr. Tredgold thinks one-eighth of an inch is requisite.

One-eighth of an inch to every 8 feet in length is the proper allowance for wrought iron, and tinned iron, and two-tenths for each 10 feet of copper pipe. If lead pipes were to be used for steam, their expansion would be about seven-tenths of an inch for every 20 feet in length. But for the return of the condensed water (which is the only use that can safely be made of them in heating by steam,) one-fifth of an inch for 10 feet will be sufficient.

Care must therefore be taken to let the horizontal steam pipes rest on rollers, that their expansion may not be checked. Fig. 13, exhibits the section of a steam pipe resting on a roller.

Two opposite attempts have been made in respect to this expansion of the pipes. For while some have endeavoured to allow room at the joints to counteract the effect of the expansion, others have endeavoured to turn the expansion to use.

Count Rumford in fitting up the steam ap-

paratus at the Royal Institution, placed drums of thin copper, Plate XIX, fig. 1 and 2, about 3 feet in diameter, which were screwed to the flanches of the pipes. The elasticity of the copper allowed it to give way, as well to the compression produced by the expansion of the pipes, as to the pulling out by the retraction of them.

At Butterly iron works in Derbyshire a loose thimble joint was used for the same purpose. The end of the two pipes *a* and *b*, fig. 3, Plate XIX, are turned true on the outside, and a thimble lined with tin is used for securing the joint, in which the two ends of the pipes work like a piston in a cylinder, about three-quarters of an inch being allowed for their motion.

Mr. Tregdold proposes to connect the pipes by fixing to one of them a short length of a pipe of smaller diameter, which slides in a stuffing box attached to the other pipe.

The first use that was made of the expansion in length of the pipes, was to open and shut the air cock at the end of them. This was effected by connecting the cock with an iron arm, the other end of which was fixed to the wall.

A similar mode of effecting the same object is shewn in fig. 10 and 11. A hole is made on the lower side of the steam pipe to allow the air to pass out, and the end of the pipe is received in a short length of a pipe of sufficient diameter to receive the steam pipe, and a thin thimble of tin between the two. This short pipe is screwed to the wall or a beam, and has, as well as the tin, a hole answering to that in the steam pipe. The air driven forward by the steam passes out by these holes, but as the steam pipe becomes hot and lengthens, its hole overshoots that in the short length of pipe, and they become closed. On the other hand, when the last portion of steam condenses and the pipe grows cold, and shortens, the holes gradually come together and admit the entrance of the air.

In 1815, Mr. Houldsworth took out a patent for discharging air, or air and condensed steam from steam pipes, in which he made use of the expansion and contraction of the steam pipes. Fig. 9, shows one of the methods adopted by him for vertical pipes, but which may be used in any other position of the pipes; *a*, is the end of the vertical steam pipe which

is closed with a plate having a hole in it for the seat of the valve; this valve, which should be from one-sixth to one-third the diameter of the steam pipe, is moved by a rod attached to one end of a lever and weight, the other end of the lever is attached by a rod to the end of the steam pipe. The valve opens into a box, *c*, from one-sixth to one-fourth the diameter of the steam pipe, which is closed at top, by a stuffing box through which the rod of the valve passes; and has a pipe on the side to convey away the air of the pipes.

When steam is admitted into the pipes, the heat causes them to expand; in consequence of which the rod attached to the end being lifted towards the fixed beam, by its action on the lever causes the valve to shut, as soon as the pipes have acquired the proper temperature for which the valve is adjusted, and thus prevents the steam from following the air which had been driven out by it. When the pipes cool, a contrary action of the valve rod takes place by the contraction of the steam pipes, and the valve opens to admit the air.

In the vertical situation in which the steam

pipe is represented, nothing but air is expelled or allowed to enter by the valve; but the same construction may be adopted for horizontal or depending steam pipes. In these cases the valve closing when the steam pipe has attained a certain temperature, the steam retained within it is condensed and forms a body of warm water; which serves as a reservoir of heat after the steam is no longer produced, until it cools to a certain temperature: when the valve opens and lets it out through the pipe, *d*, which conveys it to the cistern of the boiler.

Another method used by Mr. Houldsworth for the same purpose is delineated in fig. 7, Plate XIX, as applied to a horizontal steam pipe. To the end of the steam pipe, *a*, is applied a short pipe of smaller diameter which moves through a stuffing box into a cast iron box, *b*, closed at top, which is screwed down to a beam, *c*, fixed in the wall. In the side of the box, *b*, opposite to the place where the small steam pipe enters is affixed the rod of a puppet valve; and is so adjusted in its length by means of a nut and screw, that it may close the open end of the narrow steam pipe

when this is pushed in by the expansion of the larger steam pipe; till when the air and condensed water is carried off by the pipe, *e*, placed in the lowest part of the box, *b*. Mr. Houldsworth prefers this method when the steam pipe is of considerable length.

Having now described the various methods which are in general use for the purpose of warming buildings by steam heat, it might be expected that we should give a decided preference to some one over all others. But as the mode of supplying heat, as well as the temperature required, must altogether be regulated by the extent of the building, and the manufacturing or domestic uses for which it is erected; an intelligent workman or engineer will find each of the different kinds of apparatus before mentioned possess some peculiar advantages, under different circumstances; but which circumstances it would be quite unnecessary or indeed impossible to specify here.

CHAPTER XXIV.

OF WARMING HOT-HOUSES AND CONSERVATORIES.

After the detailed description already given of the various modes of disseminating heat in public and private edifices, by means of warm air and steam pipes, it can scarcely be necessary to recapitulate what has been said for the purpose of shewing its application in warming conservatories, or garden stoves.

The same principles and nearly similar modes of arrangement will apply, either in warming and ventilating buildings for the better preservation of the animal economy, or for the preservation and growth of plants; with this difference,—that animal life is furnished with the power of accommodating itself to every vicissitude of climate, in a greater degree than vegetable life.

The more perfect organization of man, which imparts that kind of mental energy denominated courage, is doubtless a material ingredient in sustaining the animal functions of the human race in a state of health, whether placed in the desolate regions of eternal snows, or traversing the burning sands of central Africa. The horse, the dog, and a few other quadrupeds, have also the faculty of resisting in an eminent degree the opposite extremes of climate and even the most rapid changes of temperature; whilst the lower classes of the animal creation are, apparently, deficient in this power of compensating for change of temperature, in exact proportion as they descend in the scale of organised beings.

Vegetable life is, however, widely different. Though the structure of plants may be strictly called *organised matter* (and in some of the more delicate species almost possessing the sentient principle) yet the beautiful inhabitants of the vegetable kingdom not being endued with the property of loco-motion, and consequently without the power of voluntarily increasing the circulation of their fluids and

the production of heat, they are far less able to withstand the extremes of temperature than animal life. Hence, every zone, or indeed every different degree of latitude from the equator to the polar circle, produces its peculiar genera, species, or varieties, in the interesting productions of the vegetable kingdom.

In order to compensate for the disadvantages of climate in Great Britain, we are compelled to employ artificial heat, for raising the better species of vegetables. And it is truly gratifying to witness the advancement which has been made within a few years in this highly important department of art.

Since the valuable and profound researches of T. A. Knight, Esq. on the Physiology and Economy of plants, and the establishment of the London Horticultural Society, have elevated this formerly vulgar art to a most interesting branch of science; it has produced altogether a new race of operative gardeners; more especially in the extensive public and private gardens adjacent to the metropolis. While the activity and liberality of this patriotic society in constantly importing new species or varieties of the more valuable plants

from every part of the world, and naturalizing them in this country, cannot fail of producing the most lasting advantages to the community.

With regard to the *general* management or economy to be observed in hot-houses or plant-stoves—it would not be necessary, or even proper to enter into,—in a work confined simply to the production and distribution of heat. But it may not be improper to offer a few remarks on the *specific* agency of heat in the process of vegetation.

That All-Directing Power which ordained the beautiful division of creation, the vegetable kingdom, is doubtless beyond our comprehension. But the physiology and natural functions of plants appear to be capable of easy demonstration.

We should indeed, rather refer our reader to the valuable Essays of Mr. Knight and other gentlemen, in the Transactions of the Horticultural Society, and to the Supplement of the Encyclopedia Britannica on the anatomy and physiology of plants, than to offer any observations of our own, on this subject.

It must be obvious, that the more closely

we approximate to nature in the management of plants, the more perfect will be the vegetable or fruit produced. For even in our best managed stoves, the exotic fruits scarcely ever acquire the flavour of the natural products of warmer latitudes. And it has been usual to ascribe this inferiority entirely to the want of that agency, which is imparted by the direct rays of the sun.

That the solar ray exercises a most powerful influence in the fructification of plants is well known to every able agriculturist; and this influence appears to be somewhat of a chemical character, and independent of the actual temperature; for no elevation of temperature in a pine or other fruit-stove, will compensate for the effect of the solar ray in bringing tropical fruits to high perfection.

But another cause also exists, why stove plants do not usually acquire that perfection in England which they attain in their proper habitat,—our gardeners will not study nature, in order to regulate the diurnal changes of temperature.

From the valuable meteorological observations made by Captain Sabine, R.A. during

his voyage within the tropics in the year 1822 :—and others made by Alexander Caldclough, Esq. at Rio Janeiro and part of Brazil*, it appears that even in the immediate vicinity of the equator there is a difference of temperature between noon and midnight (or rather, from about 2 P.M. and 2 A.M.) on an average, from 10° to 15°. Captain Sabine's tables shew less variation between the maximum and minimum temperature of day and night, on the coast of Africa, than in the West India Islands; which is indeed what might be expected, owing to the extraordinary humidity of the air on the African coast; which always tends to equalize the temperature, as observed in one of our previous chapters.

The finest productions of the vegetable kingdom are, however, by all authorities, acknowledged to be those of the Southern hemisphere; between the parallels of 20° and 30° latitude. And as the atmosphere of these beautiful regions is seldom saturated with vapour, except during their transient, though violent rains, the diurnal variation of tempera-

* Vide, Daniell's Meteorological Essays.

ture may be taken at a mean, according to the authority of Mr. Colebrooke*, from 20° to 22°.

Now if these diurnal † alternations of temperature were regularly produced in our garden-stoves, is it not fair to expect that vegetation would be produced in greater perfection?—if not quite equal to the natural productions of more favoured climes.

A brief view of the process of vegetation will perhaps best explain the rationale of the subject.

A certain temperature (and moisture also) is required for the germination of every vegetable *ovum* or seed. But after the seed has struck its radicle and developed its first leaves, the growth or expansion of the plant appears to increase exactly, in proportion as the temperature of the air exceeds that of the mould or soil in which it stands, and which is kept cool by the process of evaporation. For if

* On the Climate of South Africa. Journal of Science, Vol. XIV.

† It is not necessary here to consider the alternations of temperature between winter and summer, as our observations must, of course, be limited to the cultivation of the succulent class of plants termed *Annuals*.

we place a young plant in a small pot of earth, (which quickly becomes dry, and assumes the same temperature as the air) though the plant may be made to "grow" for a short period, by placing the pot in a warmer atmosphere; yet the process will become suspended whenever the mass of soil, and consequently the roots of the plant, attain the same temperature as that of the air adjacent. For *growth* is in reality, nothing more than the expansion of the branches and leaves of a plant by the heat of the atmosphere, which, leaving a partial vacuum in the capillary vessels, the sap or carbonaceous fluid is secreted by the roots and propelled upwards by the atmospheric pressure till the equilibrium is restored. But as the functions performed by the leaves of plants is very nearly analogous to those of the lungs and stomach of animals—in giving off through the medium of the oxygen of the air the refuse carbonic matter, and assimilating the juices of the plant—the greater part of the solid matter of the sap becomes arrested; forming concentric layers of vegetable or ligneous fibre.

It is necessary, however, that a certain por-

tion of the sap should return, even to the roots; in order to give that stability or basis which is essential to the future support and maintenance of the plant. Now this important object is provided for by one of the most beautiful arrangements of our Beneficent Author;—*by the diurnal variation of temperature.*

During the night season, the heat diminishes even in the tropics (as just stated,) 10° or 15°; but in temperate latitudes the change from day to night is usually during summer from 20° to 30°. Now the effect of this reduction of temperature on the functions of plants must obviously be the converse of expansion;—the contraction of the leaves and stems of plants during the night must drive back the sap towards the roots, during which process it becomes solidified and organized as a concentric layer of vegetable fibre.

The growth or expansion of plants during the day in the summer months, when the air is usually much warmer than the soil, may be therefore considered as an exhausting process; which, if pursued without intermission, would be destructive to vegetable life in a very

short period. Indeed it is uniformly observed that vegetables which have the most rapid growth (as the hop and all succulent plants) have the shortest duration, and are least able to withstand the changes of atmospheric temperature.

It seems to be a point of essential importance in the cultivation of plants, as well as in the preservation of animal economy generally, that the functions of life should be allowed regular or at least periodical intervals of rest. And whilst these intervals are employed by animals in recruiting their muscular or other vital powers; the vegetable kingdom becomes strengthened, by the deposit of successive layers of fibrous matter on the albemuneous portion of the trunk and roots; so as to enable them to sustain the exhausting process of the ensuing day, termed growth, or expansion of volume.

In the management of garden-stoves, therefore, the first consideration should be, to ascertain (with as much accuracy as possible) what is the mean heat of the hot season, by day, and also, what are the diurnal changes of temperature in those parallels of latitude,

or rather the immediate districts where each variety of the exotic class of plants attain the greatest state of perfection. For the perfection of Art, in this case, must unquestionably be allowed to be the imitation of Nature * !

By a careful adaptation of the temperature both by night as well as by day, to the natural habitudes of each plant, or where a variety of different plants are cultivated, to those which claim most consideration,—it is pre-

* The reader will find some valuable information on this subject in the observations of Mr. Colebrooke on the Climate of Southern Africa; and also in the Meteorological Essays of Mr. Daniell.—Chap. "Radiation of Heat."

Mr. Colebrooke found the mean daily variation of temperature in lat. 32° south, to be from 21 to 22 degrees; the average temperature of the warmest month (February) being 71° and the maximum heat about 100°. *Edin. Phil. Journal,* vol. v.—It is also to be observed, that in estimating the average diurnal change of temperature, great allowance must be made for the state of humidity of the air. Dr. Wells (in the beautiful Essay on the Formation of Dew) has shewn, that when the air becomes saturated with moisture, or under an opaque sky, there is frequently only a few degrees difference between the temperature of day and night; but in proportion to the clearness of the night, so does the temperature of the air become reduced by terrestrial radiation.

sumed that a much nearer approximation to the *natural* fruits of the tropical climates might be attained in our garden-stoves, or fruit-houses.

The degree of humidity in the air, both in conservatories or green-houses, as well as in the warmer class of garden-stoves, is also a point of great importance, in order to preserve the functions of plants in a state of health.

If the atmosphere of any hot-house be deficient in humidity, the transpiration of aqueous vapour from the leaves of plants will be too rapid to allow of the proper assimilation of the sap; and consequently produce imperfect or diseased vegetation.—On the other hand, if the air be too humid, it will not carry off the feculent matter of the plant with sufficient rapidity. The latter evil is, however, not so much to be apprehended as the former, in the usual management of garden-stoves of the warmer class.

The power which plants possess of absorbing heat from the action of solar light, though justly considered by Mr. Daniell as a most important part of vegetation, and who remarks, "that a scientific attention to these

particulars would tend much to benefit the art of gardening," is, nevertheless, foreign to the immediate object of the present work, and consequently must be altogether omitted here.

With regard to the mode of disseminating *artificial* heat through forcing-houses and conservatories,—it will not be necessary to enter into detail, after the description already given of the Russian and Belper varieties of stoves; and the various apparatus mentioned in the preceding chapter for transmitting heat by steam.—Only observing, that wherever flues are employed for heating buildings of this kind, great attention should be paid in allowing a sufficient surface of water to give the proper degree of humidity to the atmosphere. And that when flues or steam-pipes are required to extend any considerable distance from the fire-place, they should be either enclosed in wood cases filled with straw, chaff, or some other bad conductor of heat; or else wrapped round with straw or hay-bands as close as possible, till their admission into the building to be warmed.

It is now generally admitted that steam is the most economical agent which can be em-

ployed, as far as the consumption of fuel goes. The apparatus necessary, is undoubtedly more expensive in the first instance than flues; yet the advantages derived from steam are sufficient to compensate for any extra expence in buildings of considerable extent, by the uniformity and certainty of regulating the temperature (whatever may be that of the external air); and from it not being liable to affect the chemical properties of the air, and thus injuring vegetable life; which is too often the case when hot air-flues are employed for heating conservatories.

The temperature of air-flues or pipes considerably diminishes with the distance; but steam may be sent through cast iron pipes (having wood cases filled with any non-conducting substance, as before mentioned) to four or five hundred feet from the boiler, without any material loss of heat.

The regulation of the diurnal changes of temperature may be also effected with the utmost facility, by the stop-cocks attached to the main or branch pipes of a building fitted up with steam apparatus. In short, the application of steam for warming every building

where original expence is not an object, possesses so many advantages, even for the purposes of vegetable economy, as to be greatly superior to the use of air-flues, on any arrangement whatever.

But there is another consideration, perhaps of still greater importance, in the estimation of those who are in the daily habit of visiting these elegant depositories of the most beautiful productions of nature,—that the atmosphere of a conservatory is far less vitiated for the purposes of animal respiration, where steam is employed, than where air-flues are used.

In the latter case, the effluvium in many buildings of this description, owing to the inferior kind of fuel used, the *burnt* property of the air, and the want of adequate ventilation, is not only very oppressive to the lungs, but highly noxious to health. It should be considered, that the process of vegetation, like animal respiration, gives out carbonic matter to the adjacent air*; which delete-

* Whether the oxygenous portion of the atmosphere becomes *absorbed* by the leaves of plants, when in the shade, and is again *evolved* in the day-light or sunshine,

rious matter ought to be carried off by ventilation, as quickly as possible, both for the preservation of the healthy functions of the plant, as well as for maintaining the salubrity of the air in these most elegant appendages of our better class of mansions.

With regard to the general construction of garden-houses, and the best mode of glazing the lights, the subject has been so ably treated by Mr. Sabine, Mr. Gower, and the other eminently scientific members of the Horticultural Society, as to leave us nothing for remark, but to refer the reader to their valuable pages. The practical application of these improvements and scientific arrangements in the construction of conservatories, may be seen at Messrs. Loddige's extensive establishment at Hackney. These gentlemen exhibit a greater assortment of tropical and scarce plants, and

as supposed by some physiologists ;—or whether (as is most probable) the oxygen of the air acts merely as a *vehicle* for carrying off the carbonic feculæ of the plant,—it is not necessary to investigate here. It is sufficient to know that the vegetative process, when carried on in confined buildings, greatly vitiates the air for all the purposes of animal life.

perhaps in a higher state of perfection, than any gardens in the united kingdom.

We shall close our observations on this subject by recommending gentlemen, who are about to erect conservatories in the first instance, to pay greater attention than is usually given to the selection of a proper scite of ground.

The aspect, as is well known, may be varied according to local convenience, from the S. E. to the S.W. points of the compass. But if stove-houses, instead of being usually erected as detached buildings, and consequently exposed to the various atmospherical changes and currents of air, were built in a sort of semicircular recess or excavation in the soil, open towards the south, and banked up (to any convenient height) on the N. and N.E. so as to operate as a concave reflector; there cannot be a doubt that the natural or reflected heat would be greatly increased and economised, and of course less assistance from artificial heat required.

For it should be recollected that a great portion of the heat employed by nature in forwarding vegetation, is derived from the

reverberation or reflection of the sun's rays by the earth's surface: as is fully shewn by the uniform diminution of heat according to the elevation of any point above the level of the sea.

It is on this principle that the roof of every kind of hot-house is made to form an angle of from 30 to 35 degrees with the horizon, in order to receive the meridian sun in a vertical direction. Reflected heat following the same laws as reflection of light, (the angle of reflection being always equal to the angle of incidence) the more nearly the direct solar rays approach the perpendicular, the greater of course will be the reflected heat within a given space.

But it is not only of great importance, in point of economy, in the original construction of garden-houses, to have the walls partially surrounded by a concave screen, and the frames of the lights made of slow-conducting substances, as of hard wood, in preference to metal; but the *colour* of the interior of such edifices is perhaps a point of no less importance in the process of vegetation.

That white surfaces copiously reflect the

rays of light, whilst dark or black surfaces absorb it, has been satisfactorily proved by numerous experiments. And that light is a most important agent (independent of heat) not only in the production of those beautiful and inimitable colours which grace the Flora of the vegetable kingdom, but in the developement and perfection of fruit, has also been universally acknowledged *.

And although the refined chemical process by which plants decompose the solar ray, and select that portion of the spectrum best adapted to their peculiar nature, altogether eludes our research ; yet it is of some value to determine the simple fact,—that plants universally become etiolated and sickly when placed in dark situations ; and, on the contrary, have their beauty and vigour increased in proportion as they are exposed to the full action of solar light.—From which premises it follows,—that the less impediment which is offered to the admission of light in the erection of any kind of garden-stove, and the more white surfaces which are presented by the interior walls and

* Vide, the interesting researches of Chaptal and De Saussure on this subject.

frames—the greater will be the proportion of reflected light and heat, and consequently, the more perfectly will the functions of vegetable life be sustained.

The reflected light and heat from a white wall would be lost in the open atmosphere; but it is in a great measure retained in a conservatory, or building constructed of bad conducting materials; while an open garden wall having nothing to prevent radiation into the atmosphere, ought in every instance, to be coloured dark or black, to absorb the solar rays.

THE END.

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RUMFORD STOVES.

Fig. 1.

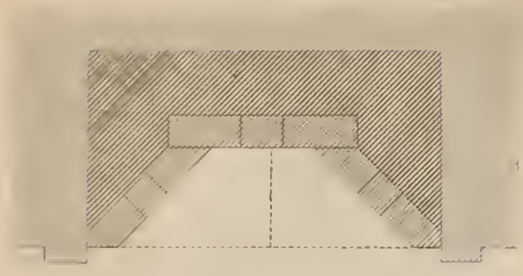


Fig. 2.

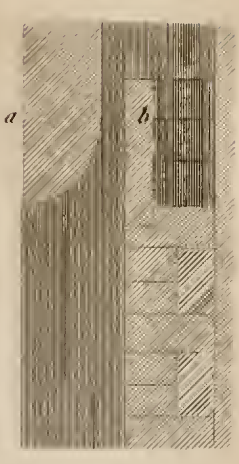


Fig. 3.

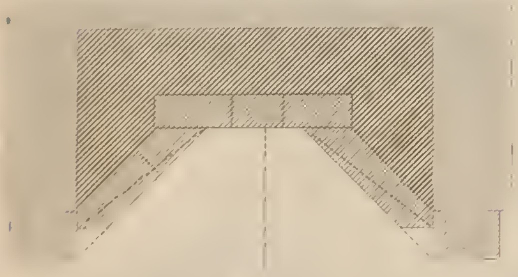


Fig. 4.

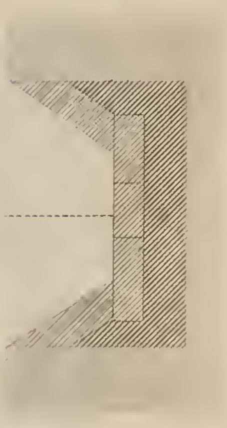


Fig. 5.

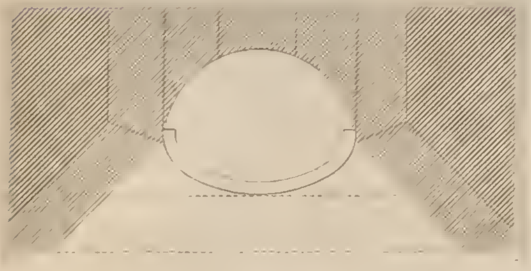


Fig. 6.

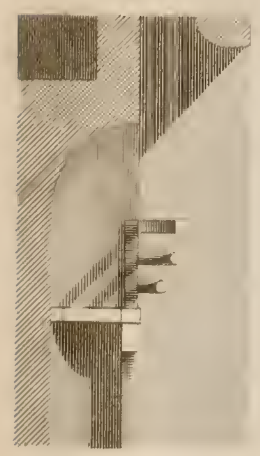
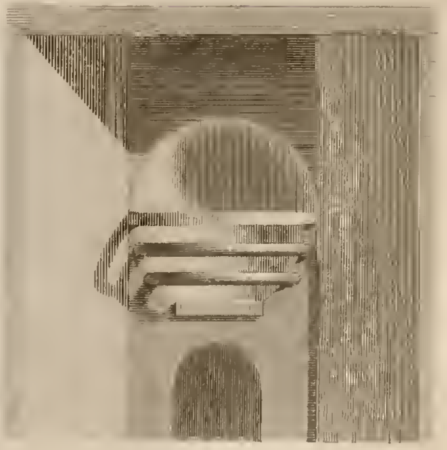


Fig. 7.



W. Alexander sculp.

London, Published by T. & G. Underwood 32 Fleet Street 182[illegible]

FANCY GRATES.

Fig. 1.

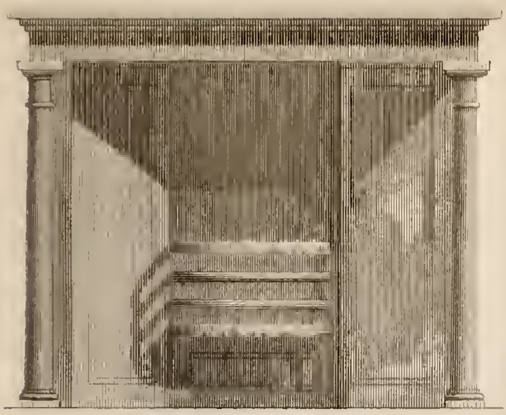


Fig. 2.

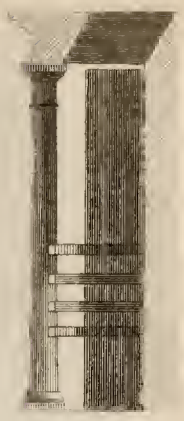


Fig. 3.

Fig. 4.

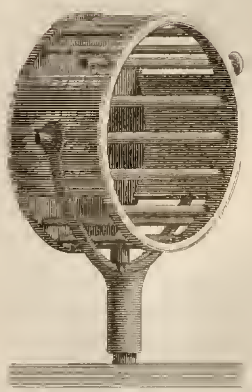


Fig. 5.

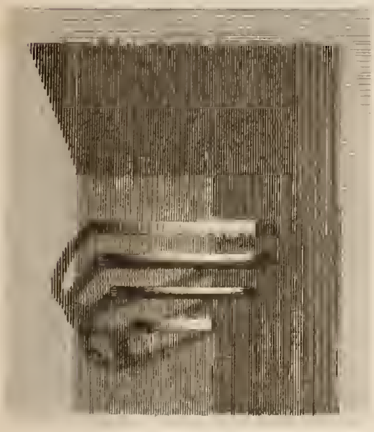
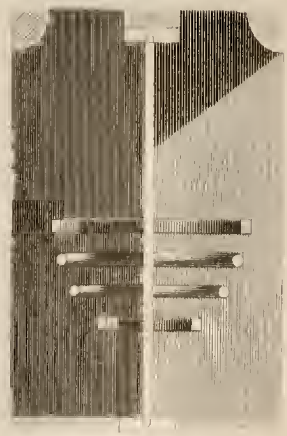


Fig. 6.



W. Alexander sculp!

London Published by T & G. Underwood, 32 Fleet Street 1825.

North European or Russian Stoves.

Fig. 1.

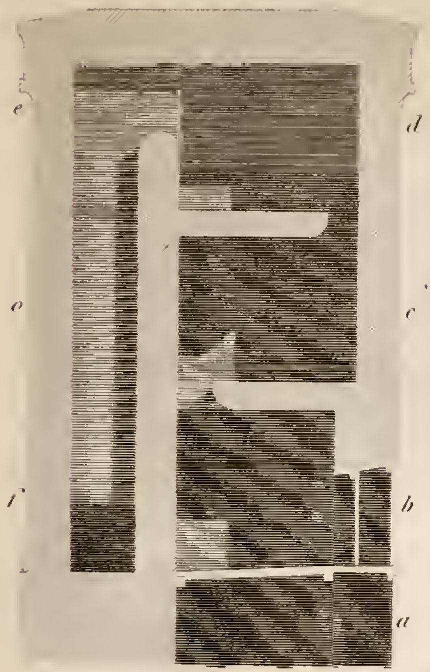


Fig. 2.

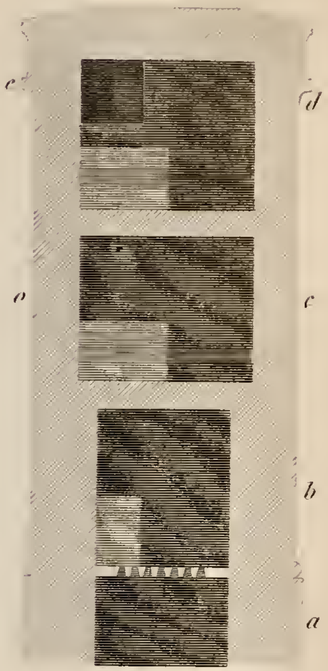


Fig. 3.

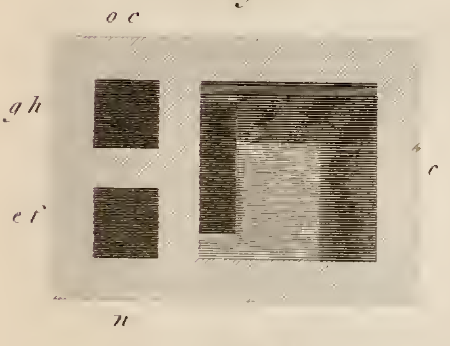


Fig. 4.

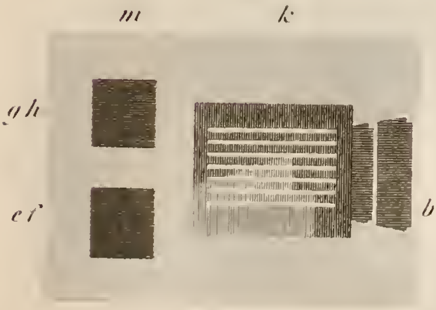
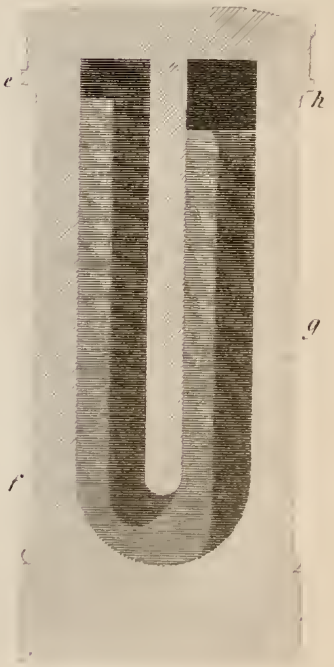


Fig. 5.



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Second Variety of North European Stoves.

Fig. 1.

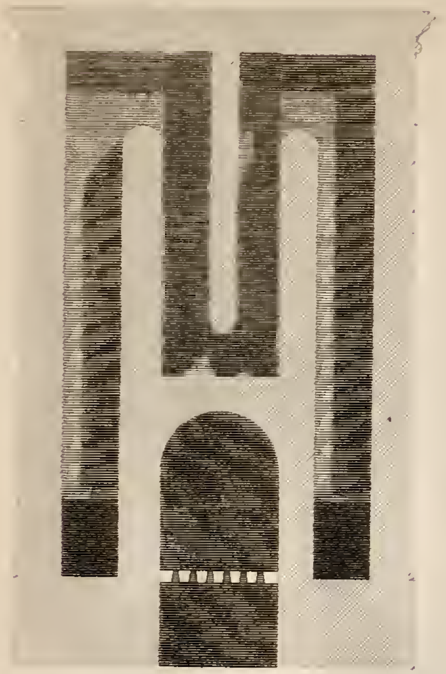


Fig. 2.

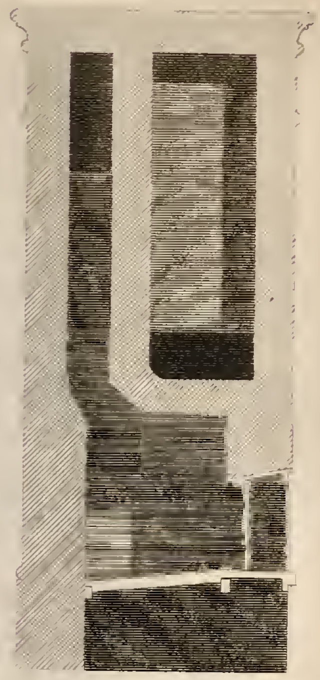
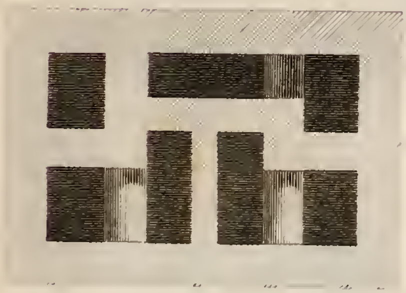


Fig. 3.



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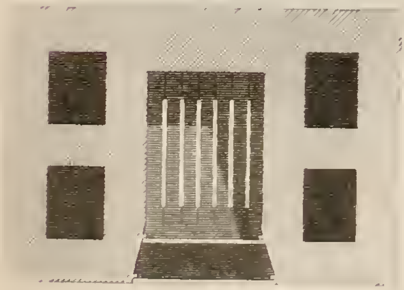

Fig. 5.

W. Alexander, sculp.

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Dr. FRANKLIN'S VASE STOVE.

Fig. 4.

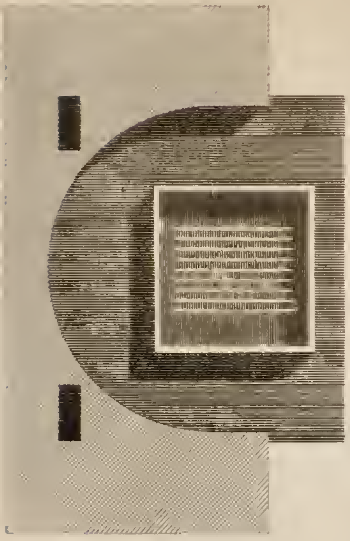

Fig. 1.

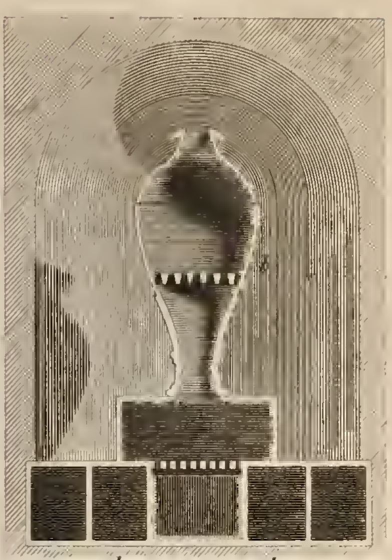

Fig. 6.

Fig. 3.

Fig. 7.

Fig. 5.

Fig. 2.

W. Alexander sculp.

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Plate 6.

FRANKLIN'S PENNSYLVANIAN STOVE.

Fig. 3.

Fig. 1.

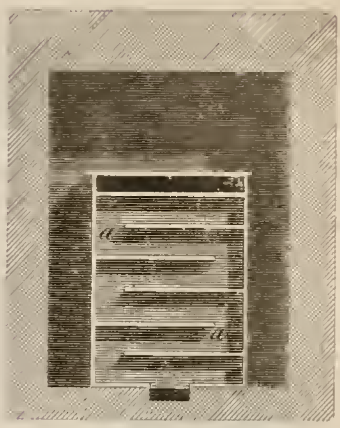


Fig. 4.

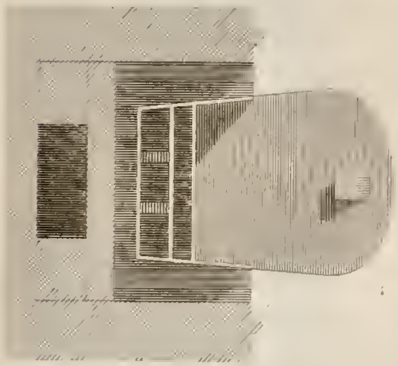
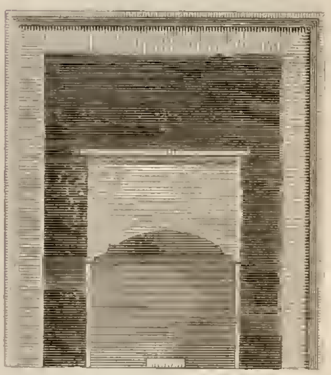


Fig. 2.



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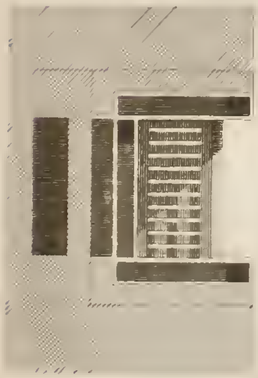
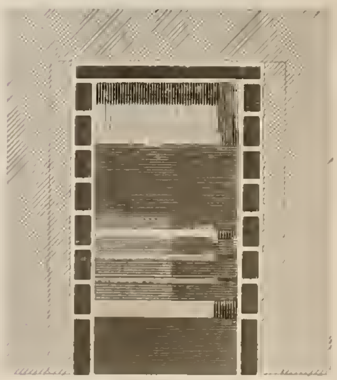


Fig. 5.



London, Published by T. & G. Underwood, 32 Fleet St. 1825.

AIR STOVE OF M. GUYTON DE MORVEAU.

Fig. 1.

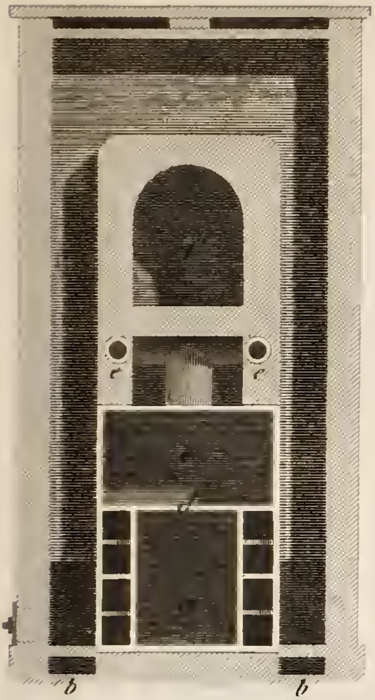


Fig. 2.

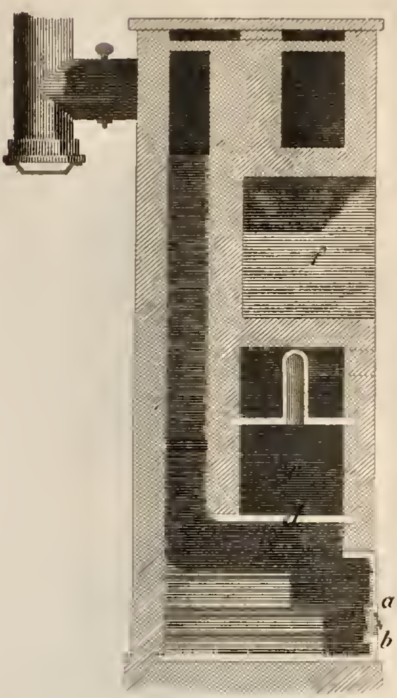


Fig. 4.

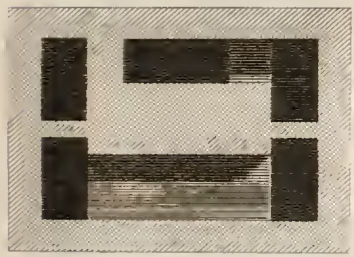
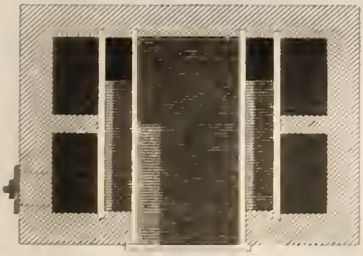


Fig. 3.

Fig. 5.



W. Alexander sculp.

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Cockle Stoves.

Fig. 1.

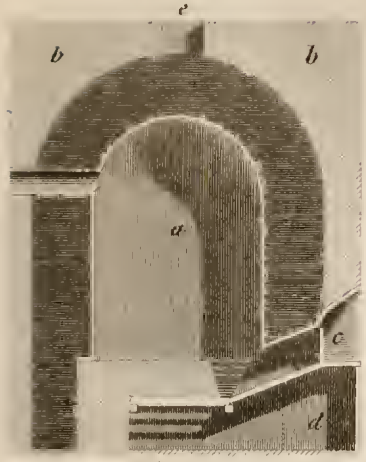


Fig. 2.

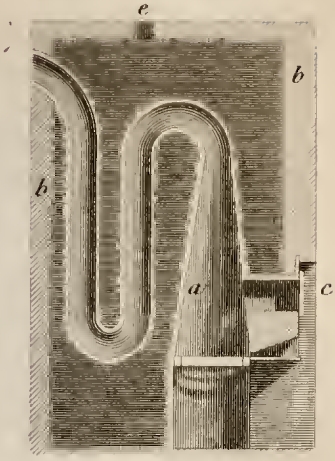


Fig. 3.

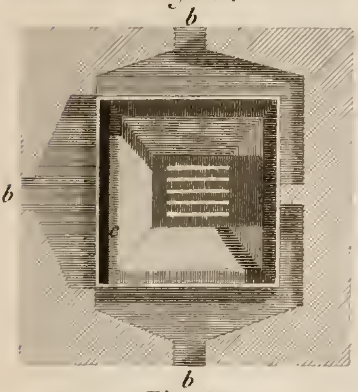


Fig. 5.

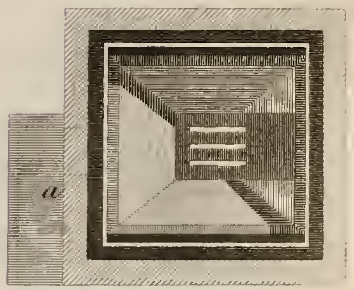
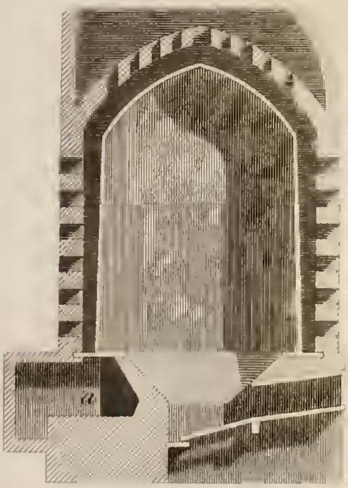


Fig. 4.

Fig. 6.



W. Alexander sculp.

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VASE COCKLE STOVES.

Fig. 1.

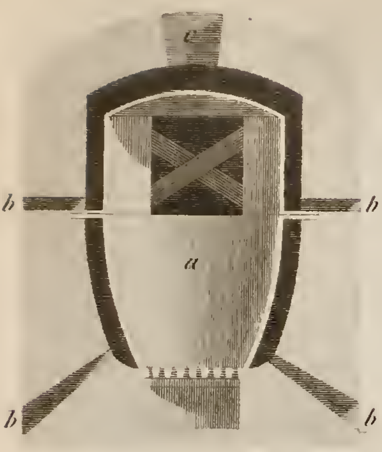


Fig. 2.

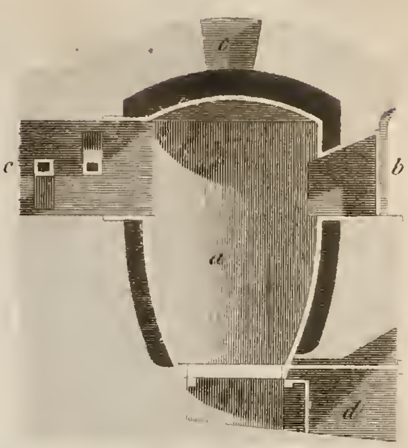


Fig. 3.

Fig. 4.

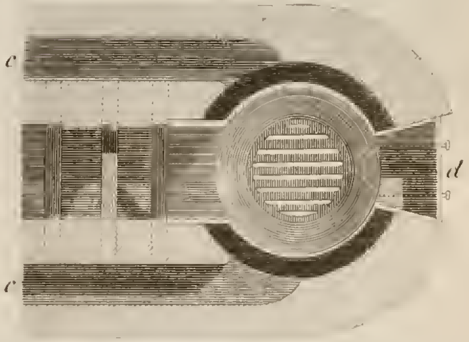
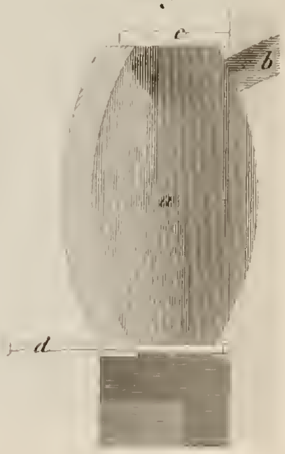


Fig. 5.

Fig. 6.



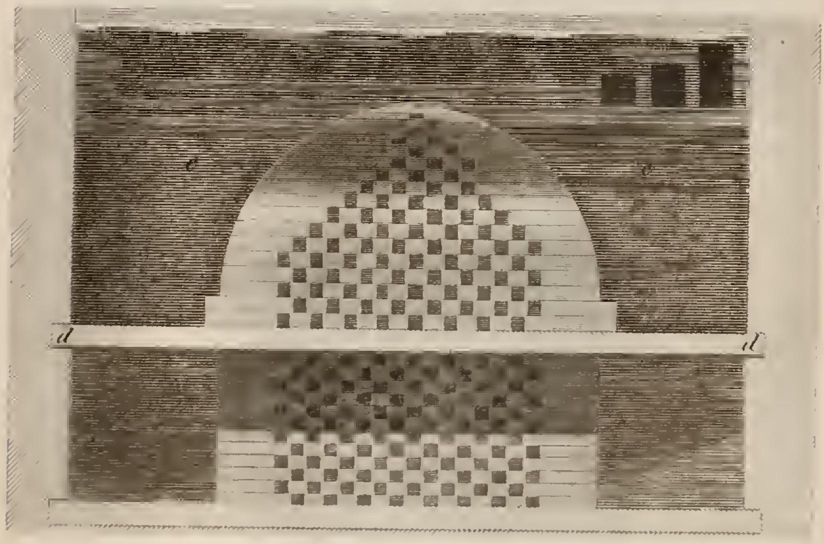
W. Alexander sculp.

London, Published by T&G. Underwood, 32 Fleet Street, 1825.

BELPER OR DERBY STOVE.

Fig. 1.

Fig. 2.



W. Alexander sculp.

London, Published by T & G. Underwood 32 Fleet St. 1825

BELPER STOVE.

Fig. 1.

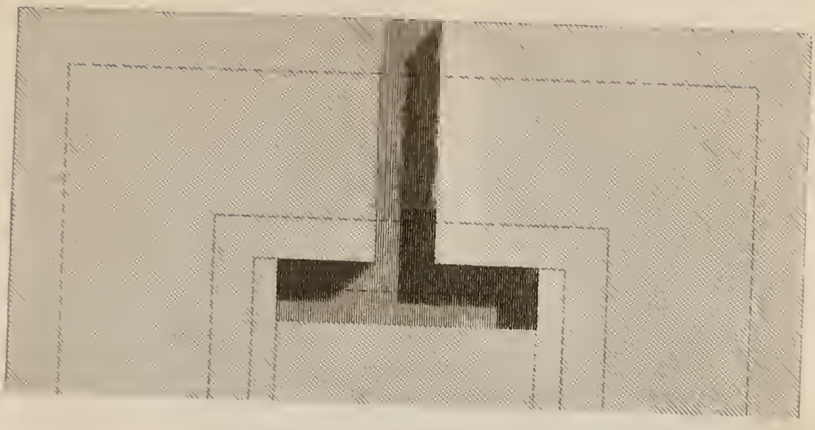
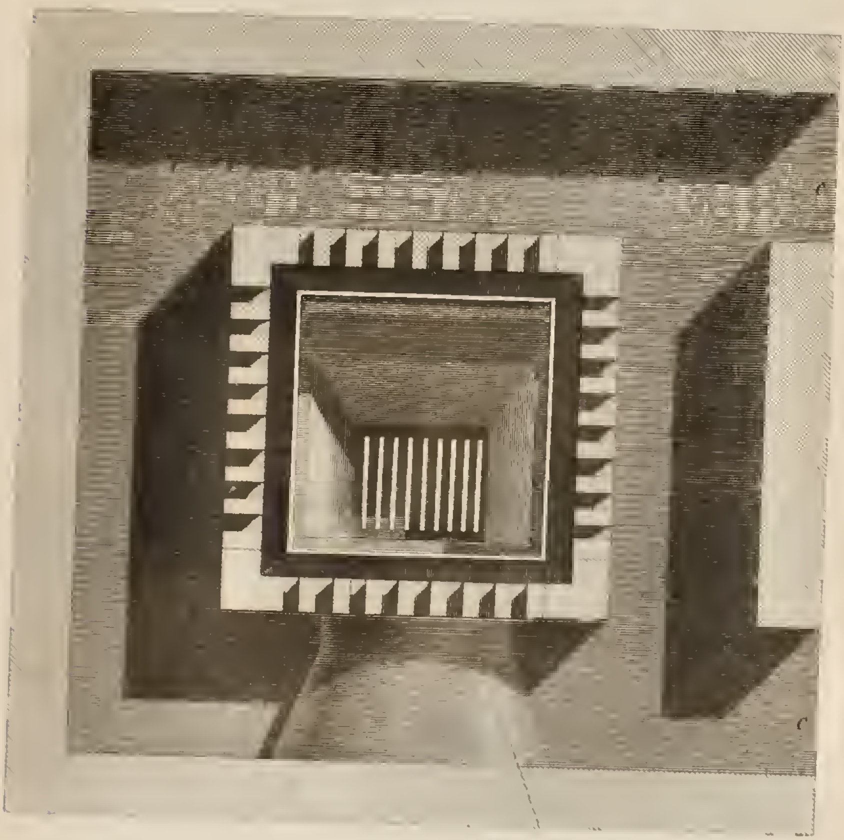


Fig. 2.



W. Alexander sculp.

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Belper Stove.

Fig. 1.

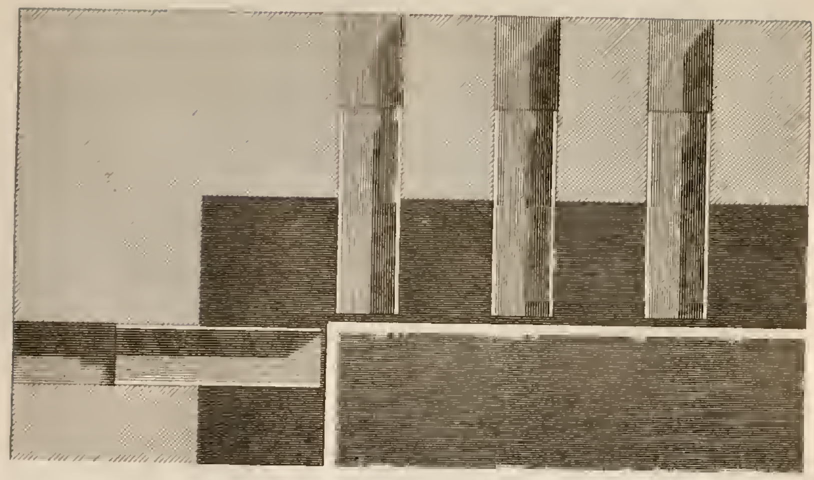


Fig. 2.

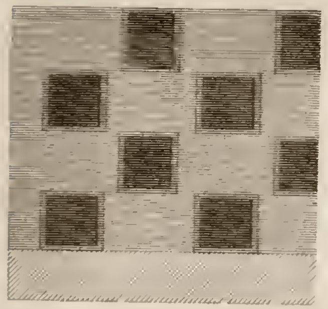
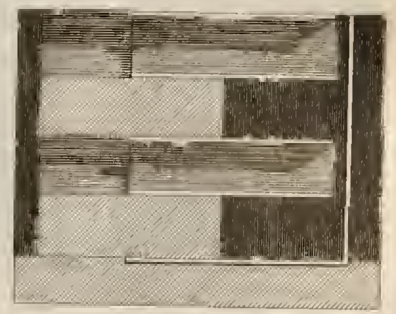
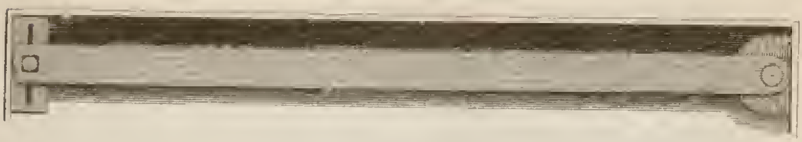
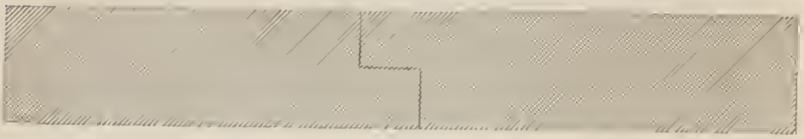


Fig. 3.







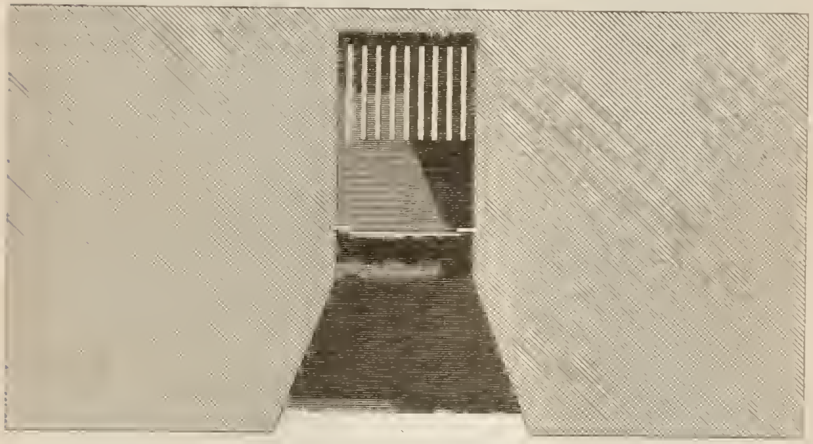
W. Alexander sculp.t

London. Published by T. & G. Underwood, 32 Fleet Street, 1825.

BELPER STOVE.

Fig. 1.

Fig. 2.



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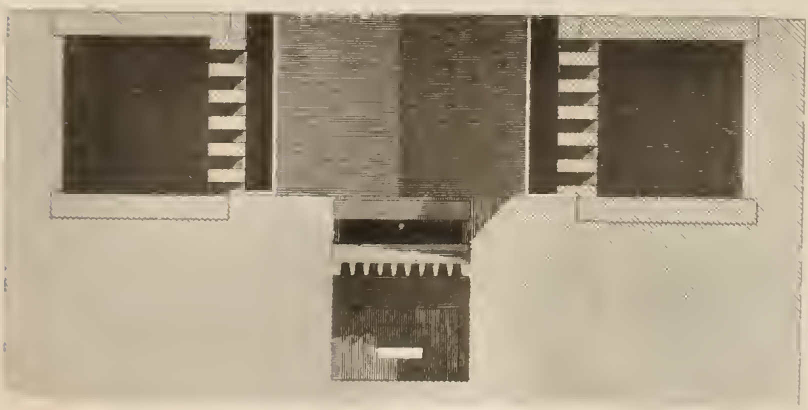

W. Alexander sculp.

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Count Rumford's Mode of Setting Steam Boilers.

Fig. 1.

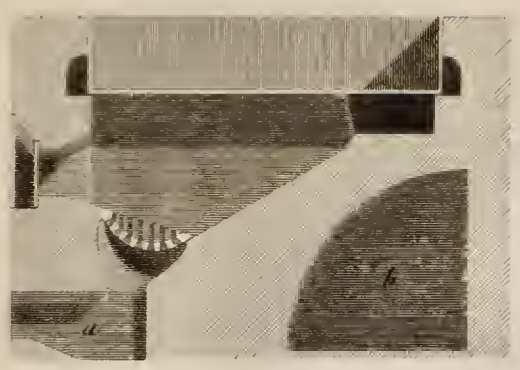


Fig. 2.

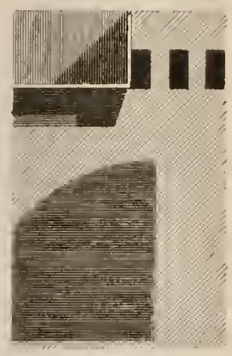


Fig. 3.

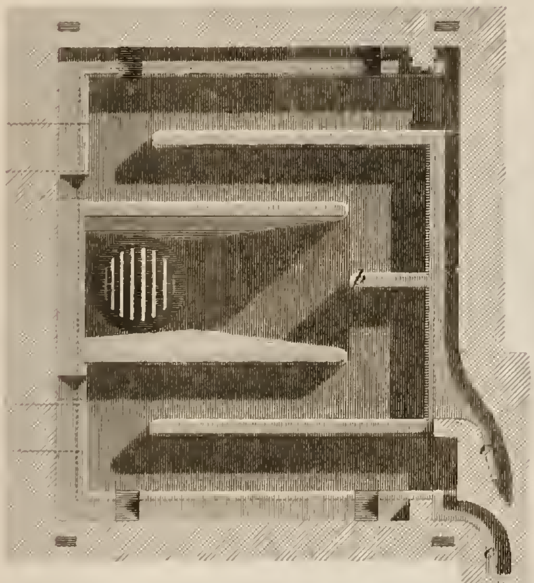


Fig. 4.

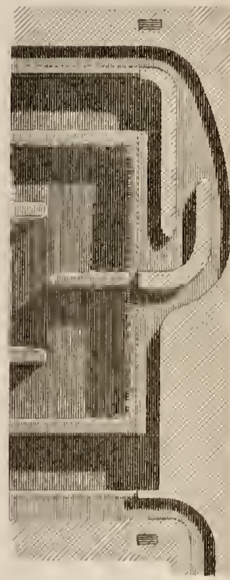
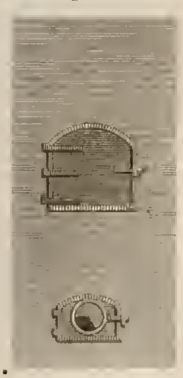


Fig. 5.

Fig. 6.



W. Alexander sculp.

London, Published by T. & G. Underwood, 32 Fleet Str. 1825

MODES OF SETTING STEAM BOILERS.

Fig. 1.

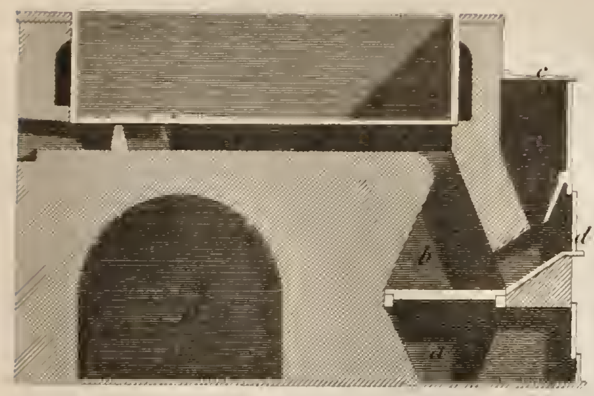


Fig. 2.

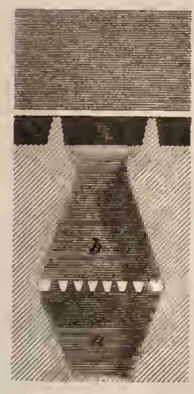
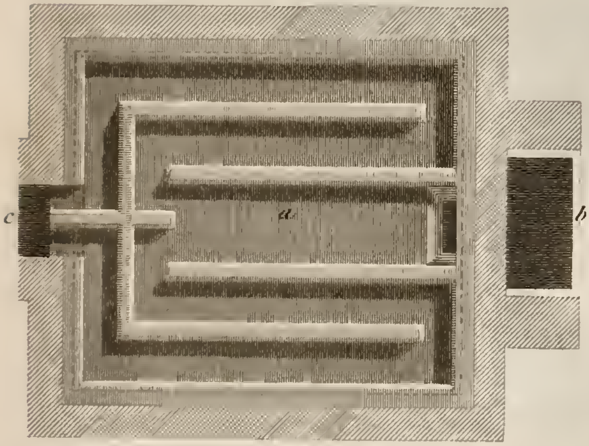


Fig. 3.



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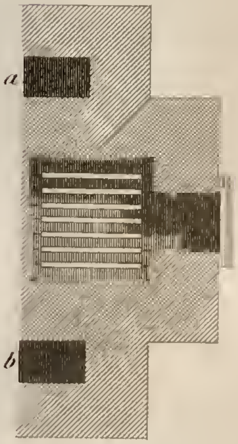
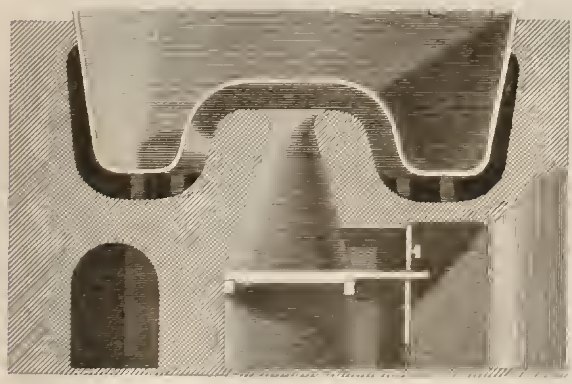


Fig. 5.



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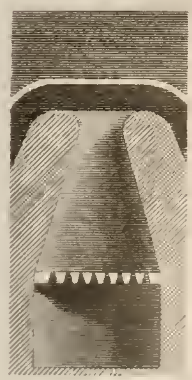

W. Alexander sculp.

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Plate 16.

MODES OF SETTING STEAM BOILERS.

Fig. 1.

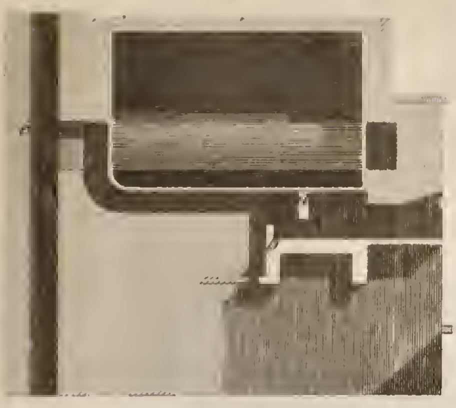


Fig. 2.

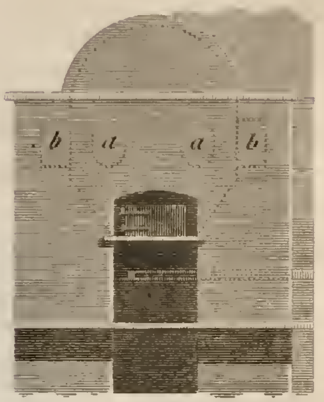


Fig. 3.

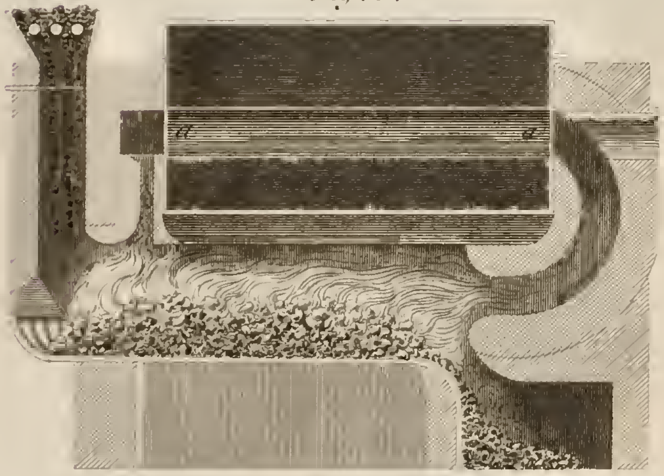
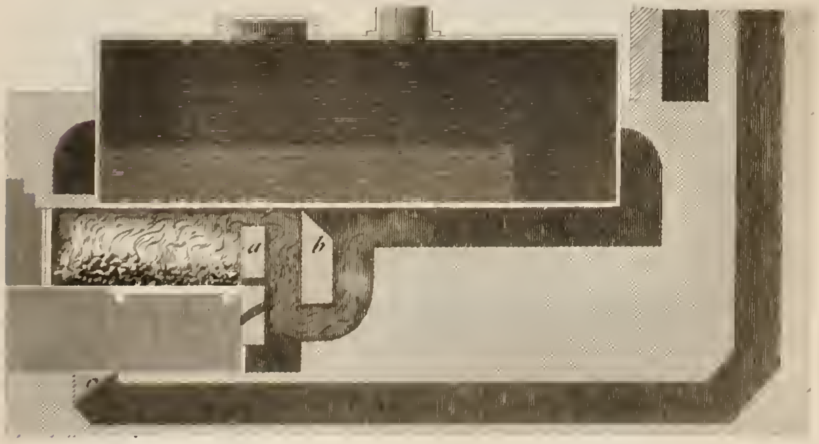


Fig. 4.



W. Alexander sculp.t

London, Published by T. & G. Underwood 32 Fleet Street. 1825

Mr. WATT'S BOILER FURNACE.

Fig. 1.

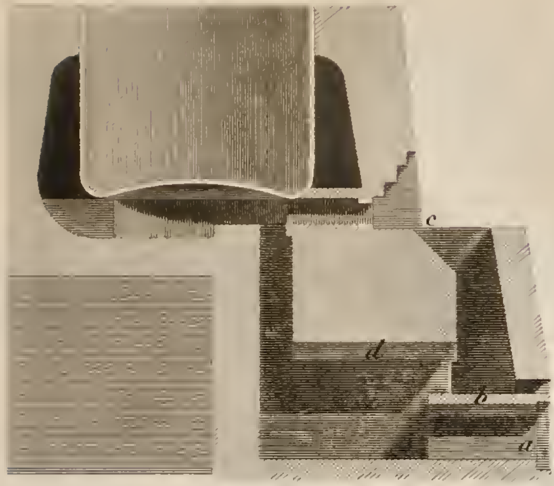


Fig. 2.

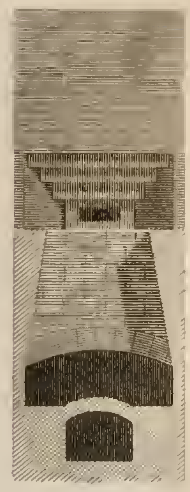


Fig. 3.

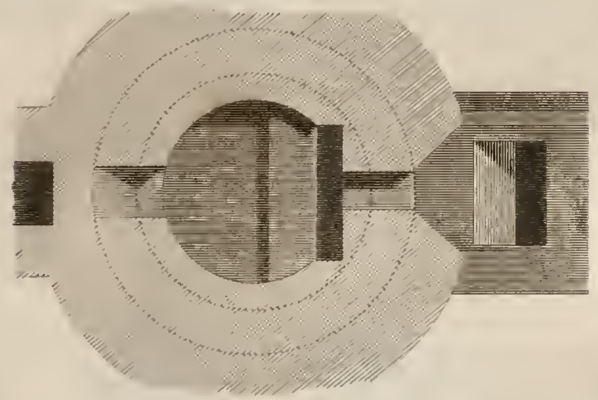
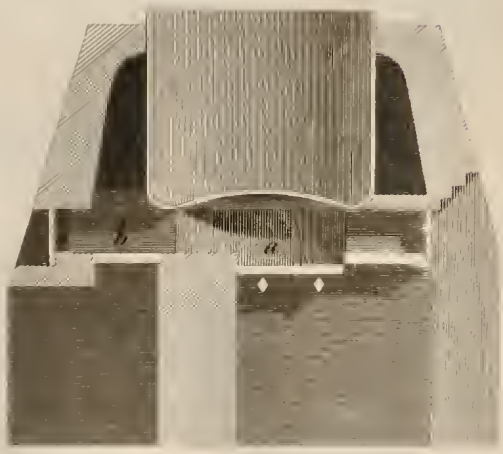


Fig. 4.

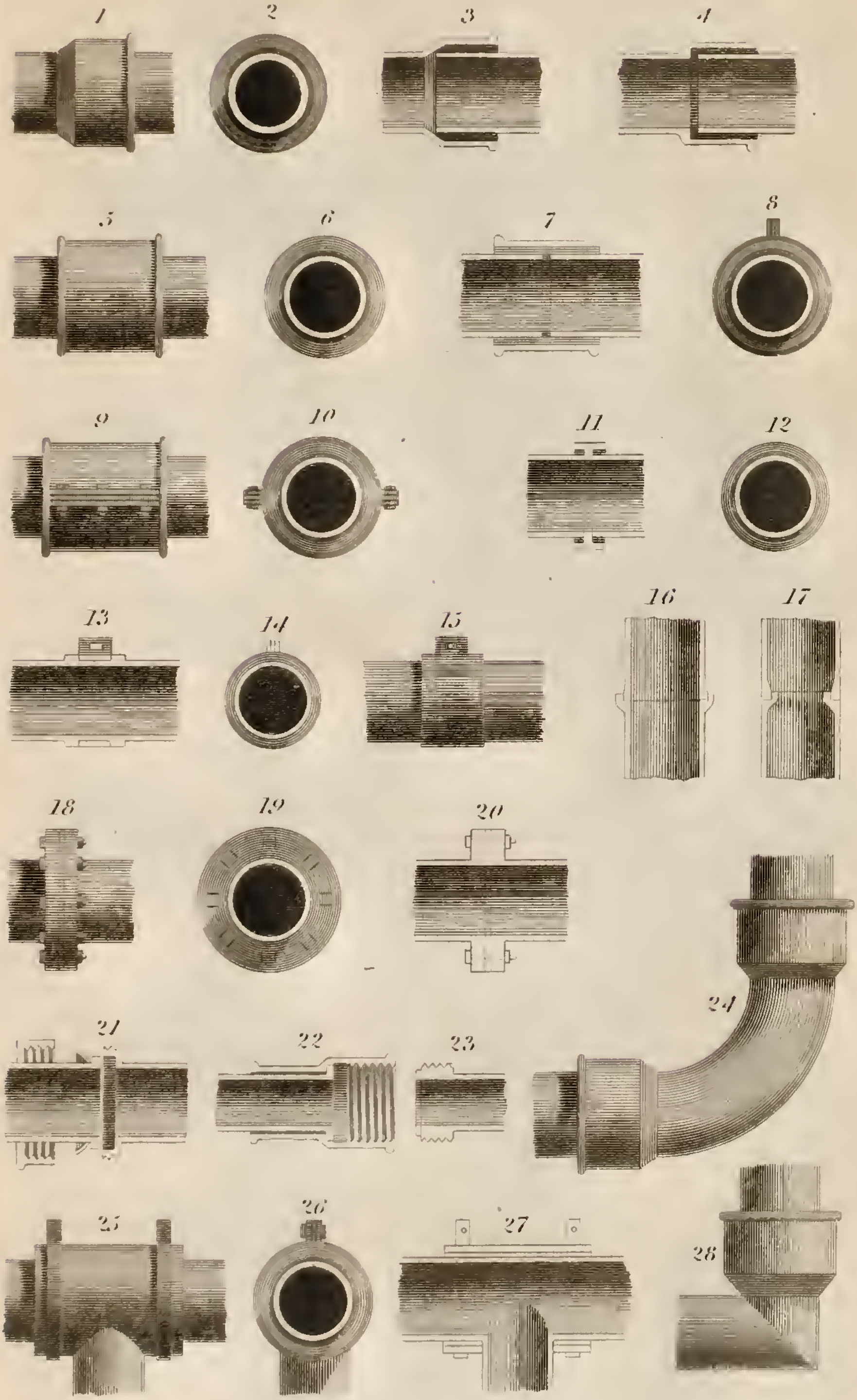
Fig. 5.



W. Alexander sculpt.

London, Published by T. & G. Underwood, 32 Fleet Street 1825

VARIOUS MODES OF JOINING STEAM PIPES.



W. Alexander sculp.

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VARIOUS APPARATUS FOR STEAM PIPES.

Fig. 1.

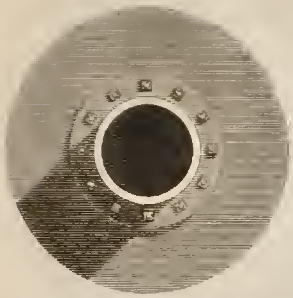


Fig. 2.

Fig. 3.

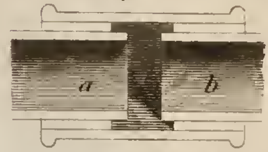


Fig. 4.

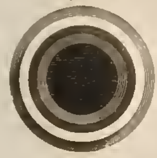


Fig. 5.

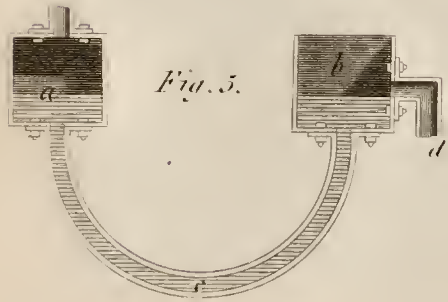


Fig. 6.

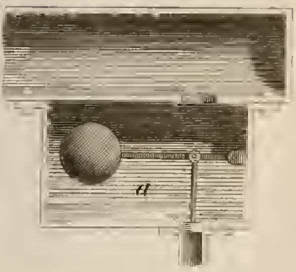


Fig. 7.

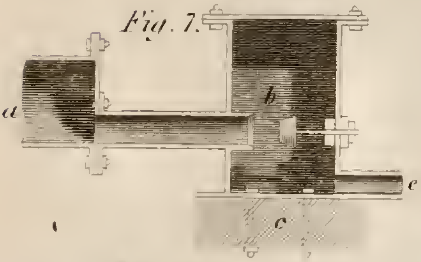
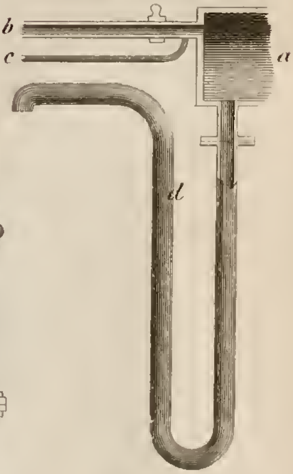


Fig. 8.



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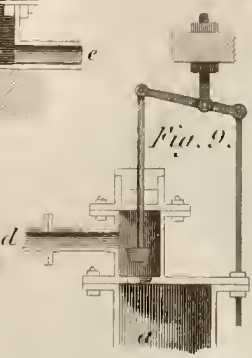


Fig. 10.

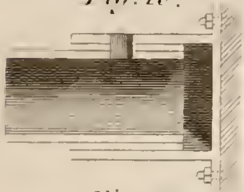


Fig. 11.

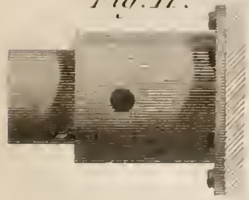


Fig. 12.

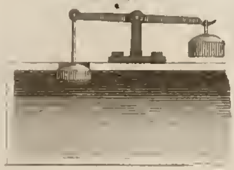
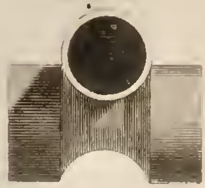


Fig. 13.



W. Alexander sculp.

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ATKINS AND MARRIOTT'S, PATENT THERMO-REGULATOR STOVE.

Fig. 1.

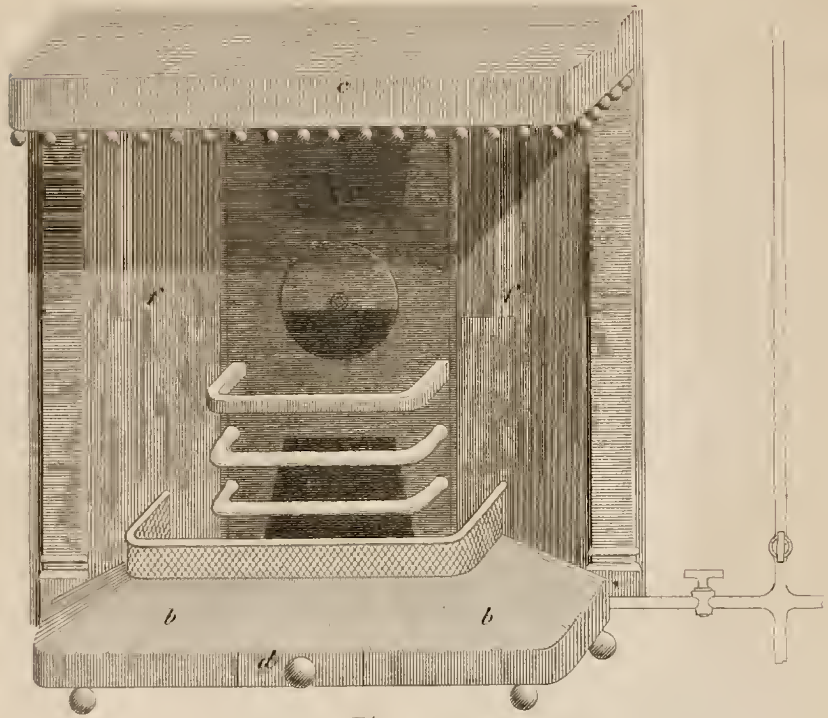
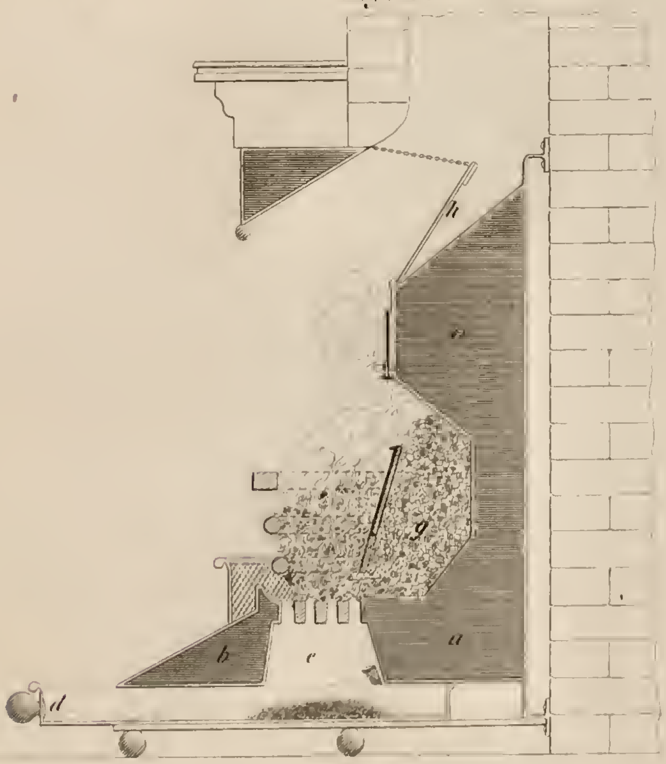


Fig. 2.



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